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DoD energy policy contends with three dimensions of the energy problem. Oil supply disruptions overseas can hurt DoD and the U.S. economy; economic interdependence means that vulnerability would remain the most pressing energy problem even if the U.S. were energy independent. Nevertheless, U.S. dependence on foreign oil sources permits foreign oil producers to charge U.S. consumers prices over free market levels. Finally, conventional oil will become prohibitively costly sometime in

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20. Abstract (Continued)

the 21st century, requiring DoD and the world's economy to make the transition to replacement fuels.

Making policy to deal with the dimensions of the energy problem requires forecasts, and making forecasts requires models. However, not all forecasting models will prove equally helpful to DoD. For example, DoD cannot place exclusive reliance on long-run economic forecasts to choose efficient means to reduce dependence, or make the transition away from fossil fuels. No consensus among forecasters exists, and the range of respected predictions is too broad. Nevertheless, models can help DoD form judgments about the outlook for future prices. This study commends the Salant and Tussing models for this purpose.

Our models can help DoD shape policies to reduce vulnerability to disruptions. The Verleger, Erfle and Mork Forecasts, and the Teisberg Oil Stockpile Model, can all help DoD hedge against the prospect of disruptions in forming supply assurance policy.

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FORECASTING MODELS FOR ENERGY POLICYMAKING

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Marshall Hoyler

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Executive Summary

FORECASTING MODELS FOR ENERGY POLICYMAKING

The energy problem confronts DoD energy policymakers with three challenges: vulnerability, dependence, and transition. Oil supply disruptions overseas can hurt DoD and the U.S. economy; even if the U.S. were energy independent, economic interdependence implies that vulnerability to disruptions would remain the most pressing energy problem. Nevertheless, U.S. dependence on foreign oil sources requires U.S. consumers to pay foreign producers prices over free market levels. Finally, conventional oil will become prohibitively costly some time in the 21st century, requiring DoD and the world's economy to make the transition to replacement fuels.

Choosing policy responses to these challenges requires forecasting, and forecasting requires models. The policymaker's problem, therefore, is not to decide whether models will be used but to select the most appropriate models from the available alternatives.

To reduce DoD's vulnerability, we recommend models that forecast oil-producer and oil-consumer behavior during disruptions. In particular, we favor the Verleger, Erfle, and Mork forecasts to form a "hedging" strategy. We endorse the Teisberg model to shape DoD's oil stockpile policy.

DoD cannot place exclusive reliance on long-run economic forecasts to choose efficient means to reduce dependence, or make the transition away from fossil fuels. No consensus among forecasters exists, and the range of respected predictions is too broad. Nevertheless, we recommend the Salant model and the Tussing model. Each embodies a different view of the structure of the world oil market and each predicts a price path in accord with that view. Both models thereby complement policymakers' judgments on policies to reduce dependence and smooth the transition.

The models we recommend will enable DoD to formulate a better internal energy policy and to participate more effectively in the development of national energy policy.

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1. INTRODUCTION

This study identifies, describes, and evaluates energy forecasting models that can help DoD energy policymakers. It is based on the premises that

(1) The Defense Energy Policy Directorate does not merely establish DoD energy policy, it also helps shape national energy policy.

(2) Discharging policymaking functions requires forecasts, and making forecasts requires models.

(3) Not all forecasting models serve DoD equally well; DoD must choose appropriate ones by using criteria that measure models' utility to DoD.

This chapter introduces the dimensions of the energy problem, expands on the premises of this study, and introduces DoD-oriented criteria for model assessment.

THREE DIMENSIONS OF THE ENERGY PROBLEM

This study assesses the usefulness of forecasting models to DoD energy decision makers. Since these decision makers also help shape national energy policy, the dimensions of the nation's energy problem deserve note here. The following paragraphs summarize the dimensions of the problem in terms of vulnerability, transition, and dependence.[1] How well the models help the decision maker to establish policy in these areas determines how useful the models are.

Vulnerability

The bulk of the world's most cheaply produced oil lies in politically unstable countries. As a result, disruptions in world oil supplies can occur at any time. This fact makes the United States vulnerable to the economic losses associated with such disruptions: price shocks, inflation,

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[1] James Plummer, ed., Energy Vulnerability, Ballinger, Cambridge, 1982.

unemployment, and decreased investment. It also means that vulnerability-reduction policies are relatively urgent and can result in substantial payoffs for DoD and the country.

Transition

Current estimates of the world's oil reserves suggest that production of fuels from these sources will become prohibitively expensive some time in the 21st Century. Accordingly, the world economy will have to make the transition from conventional petroleum to the next feasible energy source. Since the transition lies several decades into the future, preparation for it is not urgent and will not yield near-term payoffs for DoD or the country.

Dependence

Much of the oil consumed by the U.S., its allies, and its trading partners comes from overseas oil producers. Dependence is a national problem because a few large overseas producers have exercised "market power." In other words, they have limited production and made the world price higher than it would otherwise be. If the U.S. could cut demand at no cost to its domestic economy and if producers did not make offsetting supply cuts, U.S. and other consumers would enjoy a reduction in the world oil price. (Of course, demand cannot be cut at no cost; if that were possible, it would have already been done. Proposals to reduce dependence therefore raise questions about how much the nation should be willing to pay for that reduction and whether suppliers' production cutbacks would frustrate such efforts.)

Many observers confuse dependence and vulnerability. Fascination with national energy independence reflects this confusion. However, the U.S. would remain seriously vulnerable to supply disruptions overseas even if it became energy independent. Such a disruption would face U.S. allies and trading partners with increased inflation and unemployment and decreased

investment, and the U.S. economy would feel these effects quickly even if no foreign oil were imported before or during the disruption.

Policies to reduce dependence can benefit the country before it makes a transition to another energy source but do not promise as great or as immediate a payoff as policies that reduce vulnerability.

POLICY, FORECASTS, AND MODELS

DoD energy decision makers perform two basic tasks. On one hand, they establish energy policies for the Defense Department. In dealing with the vulnerability dimension of DoD's energy problem, for example, they must decide on the appropriate means to assure DoD energy supplies in the event of future conflict or supply disruptions overseas. On the other hand, they participate in the development of national energy policies. In dealing with the dependence and transition dimensions of the nation's energy problem, for example, they must respond to Congressional and Presidential requests for input in developing policy on synthetic fuel development. Discharging these dual responsibilities requires decision-making and planning, and both of these activities require forecasting.

Shaping DoD energy policy requires forecasts for the same reasons that all decision-making requires forecasts. Decision makers who claim they do not forecast are suggesting that they do not expect conditions to change significantly (which in itself is a forecast) or that any consequences resulting from their actions are both unknowable and uncontrollable. When more than one alternative choice is available, the rational decision maker will choose the one that produces the most satisfactory outcome. Making such a choice involves a consideration of its effects, which in turn requires a forecast. The decision maker's choice, therefore, is not between forecasting and not forecasting; it is how explicit to make the forecast and how to obtain it.

Forecasting can also serve DoD energy policy as an aid to planning. Forecasts can set limits that bound the usefulness of planning, establish sensible planning goals, and suggest appropriate rates of progress toward meeting those goals.

Just as forecasting is a necessary step in rational decision-making, the use of models is integral to forecasting. The decision maker's problem, therefore, is not to determine whether or not a model will be used for forecasting but to select the most appropriate model from among the available alternatives.

ASSESSMENT CRITERIA

Model selection requires model assessment, and model assessment requires evaluation criteria. This study's assessment asks how models might help DoD. In general terms, it investigates how models can help solve the problems that vulnerability, transition, and dependence pose for the Defense Department. More specifically, this study seeks to answer three questions: Is the model credible? Can it inform DoD decision makers' judgments about the likelihood and consequences of future events? Can it provide insights useful for shaping DoD energy policy?

As benchmarks for answers to these questions, this study uses the criteria summarized in Table 1-1. (Appendix A provides description of how the particular assessment criteria of Table 1-1 flow from specific DoD goals stated in Defense Energy Program Policy Memorandum 83-1.) The following paragraphs make some general observations about these criteria.

Used Elsewhere

The criterion that a model be used elsewhere provides one means to test a model's credibility in the energy modeling community as a whole. If nobody else uses the model, one has some grounds to suspect that superior

TABLE 1-1. CRITERIA FOR MODEL ASSESSMENT

Credibility as a Model

- Is the model used elsewhere?
- Does it rely on credible assumptions?
- Are its assumptions testable against evidence?

Insights about Likelihood and Consequences of Future Events/Policy Relevance

- Does the model inform judgment by showing what a particular view-of-the-world implies for future price paths?
- Does it offer insights about disruptions?
- Can it help estimate stockpiles' value?
- Does it make predictions about the transition to "backstop" technologies?

alternatives exist. More importantly, perhaps, this criterion can help DoD decision makers understand the outlook of others engaged in national policy-making. For example, the Department of Energy has employed one of the models described in this study to investigate the effect of synthetic fuels on the long-run oil price path. Its analysis led to the conclusion that development of such fuels will not necessarily set an upper bound on oil prices. Awareness of the DOE model and DOE's conclusion based on its use may not change DoD's mind on this issue, but it should permit DoD to advocate its preferred policies with greater knowledge about the strengths and weaknesses of other viewpoints.

Credible and Testable Assumptions

In most cases, model assessment does not permit simple answers to questions raised by the closely related criteria of having credible and testable assumptions. Both raise issues of judgment. Nevertheless, careful consideration of a model's assumptions is imperative. Models can aid one's thinking about difficult issues but are no substitute for it; one cannot consider a price path generated by a given model in isolation. To decide what

credence to place in a model's output one must first determine the plausibility of its assumptions. Where available evidence permits some observations about this issue, therefore, this study provides them.

Inform Judgment About Future Price Paths

This phrase "inform judgment about future price paths" is a convenient shorthand for one of this study's two key assessment criteria: Does the model show what different views of the world imply for future price paths? If a model can do that, it can inform DoD decision makers about future prices even though no model can perfectly predict the future. In other words, models permit us to say that if assumptions A, B, and C are believed, conclusions X, Y, and Z can be consistently believed. However, the intricacy and poor documentation associated with many models make it hard to determine exactly what assumptions a given model embodies. Accordingly, this study poses a relatively simple test to determine how well a model can inform judgment. The test has two parts. First, can one describe the assumptions that "drive" a model in lay-comprehensible terms? Second, where does the model stand on a continuum between simplicity at one extreme and incomprehensibility at the other? (Does it employ a relatively small number of assumptions that permit the user to intuitively grasp the model's "view of the world" or does it have so many assumptions that a user must practically become a modeler to understand the model?) When a model's assumptions are lay-comprehensible and sufficiently few for a user to grasp their implications, this study concludes that the model can inform judgment. Even if the assumptions are not acceptable to DoD decision makers, the models can help decision makers by showing what conclusions such assumptions imply.

This study considers two different time periods in applying this criterion. In assessing long-range economic forecasts, the study asks how

well a model informs judgment about prices over the next 10 or 20 years. In assessing disruptions forecasts, the study asks how well a model informs judgment about price movements during disruptions. Good performance on either dimension commends the model to DoD's attention since DoD decision makers face choices for which both kinds of price movement are relevant.

Offer Insights About Disruptions

The other key criterion in this study is whether a model contributes insights about disruptions. This criterion is important because policies to reduce vulnerability to disruptions are urgent and can bring substantial payoffs to DoD and the country. In addition, it is an important measure with which to judge long-range forecasting models. Indeed, disruptions -- and the adequacy or inadequacy of consuming countries' responses to them -- may prove the most important single factor in explaining the oil price path over this period. Accordingly, no survey of long-run petroleum "futures" is complete without some treatment of current thinking on the subject of how disruptions will unfold. Some of the forecasts LMI reviewed address this issue; this criterion highlights how those forecasts might help DoD decision makers anticipate the disruption vulnerability problem.

Help Estimate Stockpiles' Value

Officials in the Departments of Energy and Defense have expressed interest in the question of the Federal government building a Defense Petroleum Reserve. Oil market forecasts play a critical role in estimating the value of such a stockpile: analysis must take into account what the petroleum price path will look like over the life of such a reserve. In addition, analysis must consider whether expected benefits exceed the expected cost of building such a reserve. The "price path" criterion covers the former point; the "stockpile value" criterion prompts explicit discussion of the latter.

Predictions About the Transition to "Backstop" Technologies

Energy analysts use the term "backstop" to refer to technologies that will one day replace conventional petroleum fuels. Many national policies (e.g., Federal subsidies for the U.S. Synthetic Fuels Corporation) seek to prepare the U.S. economy to make the transition to these alternative technologies. DoD plays a role in shaping these national policies and therefore needs to know the current state of analysis of the transition. This criterion prompts explicit consideration of how available forecasting models can help DoD decision makers approach this problem.

THREE KINDS OF OIL MODELS

This study applies the assessment criteria introduced above to a variety of models used to analyze the long-run energy future. Before considering them directly, two points about these models are worthy of note.

First, all of the models analyzed are primarily concerned with developments in the world oil market. This focus is justified from the standpoint of internal DoD energy policy because oil provides the great bulk of "mobility energy" critical to training in peace and prevailing in war. However, this focus is also justified from the standpoint of national (and, indeed, international) vulnerability. As energy analyst Daniel Yergin remarks,

> ... it is oil that is at the center of the energy question and our current predicament. It is the change in the supply of oil that has changed the character of international politics. It is a series of oil shocks, not coal or natural gas shocks, that has sent such reverberations through the world economy. It is oil that provides half the energy used in the world every day. ... It is oil that has made world politics so vulnerable to what happens in the Middle East. It is oil that has turned the matter of energy supply into an overarching security issue.[2]

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[2] Daniel Yergin and Martin Hillenbrand, eds., Global Insecurity: A Strategy for Energy and Economic Renewal, Houghton Mifflin Company, Boston, 1982, pp. 20-21.

Second, the oil market forecasting models examined in this study fall into three categories:

(1) economic models that explicitly project oil prices (described in Chapter 3);

(2) decision analysis models that require decision makers to state their subjective judgments about future developments in the world oil market and that show the implications of these judgments on future policy choices (described in Chapter 4); and

(3) models that forecast oil-producer and oil-consumer behavior in future disruptions (described in Chapter 5).

2. FINDINGS AND CONCLUSIONS

This study has reviewed forecasting models in the broadest sense of the term. It has focussed on three different types of models and has assessed specific models of each type against criteria appropriate to DoD use of the models. This chapter summarizes that assessment, pinpoints various challenges faced by energy policymakers, and recommends models that can be used to assist in understanding and meeting the challenges.

MODEL ASSESSMENT SUMMARY

Table 2-1 provides LMI's assessment of the six models that this study commends to DoD's attention. All six warranted consideration, given their credibility as models as measured by the criteria that they are used elsewhere and rely on credible and testable assumptions. Of the six, five are able to inform judgment concerning future prices. (In other words, these five models can help decision makers see what a given view of the world implies for future price paths.) The sixth, the Teisberg model, is also listed in Table 2-1 because, although it does not inform judgment about future prices, it does provide policy-relevant insights on oil stockpiles and the nature of disruptions.

Analysis of forecasting models will serve the Energy Policy Directorate only if it helps DoD decision makers solve practical problems. The model assessment summarized in Table 2-1 identifies potentially useful analytical tools and specifies policy areas for which they provide relevant insights. However, Table 2-1 does not state what these insights are. Accordingly, the balance of this chapter summarizes the policy-relevant insights from models Table 2-1 commends.

TABLE 2-1. MODEL ASSESSMENT SUMMARY

Category[a]	Model	Used Elsewhere?	Assumptions:		Inform Judgment About Future Prices?	Insights About:		
			Credible?	Testable?		Disruptions?	Stocks?	Transition?
Long Range Economic Models	Salant	Yes	Fair	Fair	Yes (long-run)	No	No	Yes
	Tussing	Probably	Fair	Fair	Yes (long-run)	Yes	Yes	Yes
Decision Analysis Models	Teisberg[b]	Yes	Good	Fair	No	Yes	Yes	No
Disruption Forecasting Models	Verleger	Yes	Fair	Good	Yes (disruption duration)	Yes	Yes	No
	Erfle	Yes	Fair	Good	Yes (disruption duration)	Yes	Yes	No
	Mork	Yes	Good	Fair	Yes (disruption duration)	Yes	Yes	No

[a]LMI researched the DRI and WOIL long-run economic models and the Saaty forecasting model in preparing this report. This table does not list those models for two reasons. First, neither model helps DoD decision makers easily see the view of the world associated with the model's forecast price path. Instead, each model requires decision makers to become minutely familiar with details and with the rationale for particular input assumptions before drawing any firm conclusions about why the model forecasts as it does. (See Appendix B for illustration of this point.) Thus, neither model informs judgment about future prices in the sense LMI's criterion implies. Second, neither model meets other criteria so solidly as to warrant commending them to DoD's attention.

[b]The Teisberg model provides solid insights about stocks and disruptions. Accordingly, LMI commends that model to DoD's attention despite the fact that it does not inform judgment about future prices.

The following summary takes the dual role of the Defense Energy Policy Directorate as its point of departure. In other words, it reflects the premise of this study that DoD energy policymakers not only establish DoD energy policy but also help shape national policy. This dual role implies DoD interest in forecasts not only as they relate to DoD energy problems but also as they relate to the nation's energy problems.

FORECASTING MODELS AND DoD's ENERGY PROBLEMS

In Chapter 1, the study noted that the energy problem had three dimensions -- vulnerability, transition, and dependence. How will the models reviewed here help DoD cope with each of these dimensions? Answers presented below are immediately relevant to DoD policy on the vulnerability dimension of the energy problem but not to those on the dependence and transition dimensions. This results from the fact that policy measures to address each dimension vary in their immediacy and in the time period they need to take effect. Vulnerability poses the prospect of enormous losses at almost any time; policies to reduce vulnerability [e.g., a larger Strategic Petroleum Reserve (SPR)] can, therefore, have an immediate effect. By contrast, transition is a problem the U.S. economy faces over the next several decades. As a result, current policymakers may decide that they do not attach any urgency to detailed planning to deal with that transition. Whatever their decision, efforts to develop alternative technologies require 10 to 40 years to show results.[1] Dependence imposes daily losses on the U.S. economy. However, reduced dependence might not reduce those losses because of offsetting production cutbacks. In addition, dependence losses are much smaller than the losses that even a small disruption would create. Policies to reduce dependence require three to ten years to show results.

[1]This time estimate, and others in this paragraph, are from Plummer, Energy Vulnerability, op. cit.

Will Models Help DoD Reduce Vulnerability to Disruptions?

The three disruption forecast models and the Teisberg decision analysis model bear policy implications for DoD. Even though defense decision makers may not agree with these implications, they should be aware of them. These implications are summarized in the following paragraphs.

Past Problems and Future Problems. DoD does not wish to repeat its experiences during the 1979 supply disruption. Understandably, therefore, its energy policy has sought to protect it from problems similar to those faced then. Analysis of disruption forecasts suggests, however, that some problems characteristic of past disruptions may not recur.

Chapter 5 shows that in 1979 overseas crude producers frequently postponed increasing their contract crude prices to spot market levels. Their behavior encouraged stockbuilding by oil firms and may have been the ultimate cause of DoD's difficulties in obtaining product supplies. Analysis suggests that crude producers may not behave this way in the next disruption. If so, DoD will probably not face difficulties in obtaining supplies although it will clearly have to pay sharply higher prices.

Even if overseas producers do delay crude price increases in future disruptions, it is not clear that U.S. firms will delay product price increases. Those firms may judge that such delays did not protect them from an irate Congress before; they might also judge that a changed political climate will encourage use of "honest" prices that reflect actual supply and demand conditions in the world. In that case, too, DoD will have no problems acquiring needed supplies as long as Congress approves the necessary additional appropriations.

Of course, it is possible that a future disruption may recreate the 1979 situation. Overseas producers may delay crude price hikes; large U.S.

firms may delay product price hikes and, to minimize political reprisal, allocate petroleum product on some basis other than price. In such circumstances, large firms may choose not to respond to DoD solicitations when their predisruption DoD contracts run out. In anticipation of this prospect, DoD should avoid sole reliance on major firms as an element of supply assurance policy. DoD should also secure authority to pay spot market prices.

Price Controls and Allocations. Widespread opposition to price controls and allocations exists within the energy analysis community. Although this opposition can be overridden by Congress and the President, DoD may wish to develop supply assurance policies that provide alternatives to price controls and allocations. Such alternatives will permit DoD to hedge against the possibility that the government will, in fact, do what current policy promises and "let the market work" in any future disruption.

Disruption Tariff. Some disruptions forecasters favor imposing a disruption tariff, while others do not. In a future disruption, policymakers will choose one course or the other, and their choice will affect DoD. Imposition of a tariff will increase domestic prices over levels prevailing on the world market, perhaps presenting DoD with a relatively high domestic price and a relatively low foreign one. On the other hand, if no tariff is imposed, DoD faces the same price here and abroad. It is not clear which outcome will benefit DoD more; it is clear, however, that DoD should define a position on this issue and be prepared to defend that position within the government.

Stockpiles. This study's analysis of disruption forecasts and the Teisberg model bear several implications for DoD stockpile policy. The Teisberg model can inform DoD judgment regarding drawdown decisions. It shows that, even if pessimistic about the probability of future disruptions, a policymaker can maximize the national benefit from the reserve by drawing it

down quickly during disruptions. This finding can help DoD argue for drawdown even if other governmental agencies counsel restraint.

Disruption forecasts as well as the Teisberg model address drawdown strategy. The Teisberg analysis presumes that any SPR drawdown would be done by auction; Verleger argues for allowing private parties to determine the timing of SPR drawdown. Neither strategy would permit a DoD veto over SPR drawdown, and both are consistent with "directed sales" to DoD only if DoD is willing to pay the spot price for crude.

<u>Will Models Help DoD Make Policy for the Transition?</u>

The prospect of a transition away from fossil fuels raises three questions for both national and DoD energy policymakers:

(1) When (and at what price) will the national economy arrive at the energy "backstop?"

(2) Will development of alternative fuels set a ceiling on rising prices of conventional fuels?

(3) Can the market alone anticipate this development or should government have a role?

None of the models surveyed in this study permits a confident answer to the first question. In Chapter 3, a review of long-run forecasting models shows that considerable uncertainty surrounds the price path that should be anticipated for conventional fuels. Equal or greater uncertainty surrounds the future price and production profile of substitutes.

Salant's model (described in Chapter 3) has been used to derive an answer to the second question. DoD decision makers should not necessarily expect relief from higher energy prices as a result of development of shale oil or some other substitute energy. Only when the backstop fuel is available in enormous quantity will its price put a ceiling on conventional energy prices.

None of the models examined speaks directly to the question of whether free market forces alone can provide a smooth transition from conventional petroleum to the next energy source. Salant's analysis does suggest that, as oil becomes more scarce, it will rise in price; rising oil prices will then encourage the development of alternative sources. However, that does not imply that there is no role for government participation.

Will Models Help DoD Make Policy Regarding Dependence?

United States dependence on overseas producers raises two questions for national energy policymakers and DoD energy policymakers:

(1) If the U.S. reduces its dependence on foreign oil, will overseas suppliers respond with offsetting production cuts, leaving the world price no lower than before?

(2) To the extent that overseas suppliers do not cut production, what is it worth to the U.S. to reduce dependence?

If a highly reliable means for forecasting prices were available, national policymakers could rely on it to make policies regarding dependence. It could help them decide how much to spend to reduce consumption and thus produce an actual price path lower than the one forecast. Similarly, DoD could use such forecasts in making weapon system life cycle cost estimates and cost-effective acquisitions. With the dependence dimension of the nation's energy problem, the critical question is whether available models provide the required reliable forecasts.

The analysis in this study suggests that available models do not provide such forecasts. No consensus among forecasters exists. It is possible to define ranges among forecasts, but these ranges are too broad to be much help in making policy. Reliance on a single forecasting model or service will not suffice either; the same forecaster can change predictions drastically from one year to the next.

Nevertheless, two of the models surveyed can inform DoD energy policymakers' thinking about future price paths and thus about dependence. Neither model justifies crash energy efficiency programs on grounds that oil prices will move ever upwards. The Tussing model shows why real oil prices might rise no higher than 1980-1981 levels for the rest of this century. The Salant model gives grounds for believing that oil prices will eventually rise again, barring the now-unforeseen development of an abundant and cheap oil substitute. However, given the dominant-firm/competitive-fringe structure of the world oil market, Salant shows that oil prices are unlikely to rise more quickly than the rate of interest.

Tussing also argues that the world oil market is inherently cyclical, on the basis of the contrast he observes between the long-run and short-run price responsiveness of both oil supply and oil demand. This proposition tells DoD and the nation that they must be prepared to handle dramatic oil price fluctuations. Abrupt downward price shifts will not hurt DoD except to the extent that they lull policymakers into a false sense of security. However, abrupt upward price shocks can present serious problems for both DoD and the nation. The prospect of these price shocks motivates interest in the vulnerability dimension of the energy problem.

CONCLUSIONS

The forecasting models reviewed in this study provide some insights that can help in establishing appropriate policies for dealing with energy dependence and the energy transition. However, the analysis shows that these models are especially relevant to policy when they deal with energy vulnerability. DoD decision makers may not accept all of the policy recommendations from the models reviewed here, but awareness of models' results will help DoD shape and advocate the policies it does choose.

3. LONG-RANGE ECONOMIC FORECASTS

This chapter describes and assesses economic models that provide long-range oil price projections. First it describes the types of model structures used to make forecasts and introduces the major distinctions analysts draw in categorizing forecasting models. Next, it provides a review of the forecasts surveyed, and finally, it presents an analysis and assessment of two models that are commended to DoD's attention.

MODEL STRUCTURE

Forecasting models reflect several different approaches to predicting future oil prices. Key differences among these approaches define "model structure." This section outlines some of those distinctions and then discusses some examples of structurally different models.

Two types of models are used to make forecasts. On one hand, forecasters may rely on their mental image of what forces are critical in shaping future prices and may project prices on that basis; for convenience, that type of model is referred to as a "qualitative" model. On the other hand, forecasters may build an explicit mathematical representation of critical factors and of how those factors affect one another. Such a model may or may not be programmed and run on a computer. For convenience, that type of model is referred to as a "quantitative" model.

Decision makers who rely on forecasts must recognize that the qualitative-quantitative distinction refers to points on a continuum rather than a rigid division between wholly dissimilar ways of looking at the world. Qualitative modelers may rely implicitly or explicitly on the output from, or insights of, mathematically specified models. Similarly, quantitative models have to embody some basic qualitative "view of the world." Unless

sound thinking lies behind the systems of equations that such a model comprises, elaborate quantification will result in spurious precision rather than useful insights. In addition, most quantitative models require some "steering" from the user, which represents a "qualitative" input.

Since computer models generated most of the forecasts reviewed in this study, the rest of the categories noted below refer to quantitative models.[1] The most important distinction between such models pertains to the degree of foresight ascribed to the economic sectors (consumption, production, etc.) in them. In <u>intertemporal optimization</u> models, at least one sector enjoys perfect knowledge about some future developments. In <u>recursive simulation</u> models, by contrast, sectors behave only on the basis of information from past and current events. A second broad distinction involves the way that parameter values are specified for use in the model. <u>Econometric</u> models rely on statistical analysis of past historical data to provide numerical estimates of parameter values. <u>Systems dynamics</u> models are built with parameter values specified by the modeler although model builders try to relate these estimates to historical data. ("Systems Dynamics" also connotes a model with multiple feedback paths that tend to determine many parameters <u>within</u> the model as a simulation is run.) Still other models leave broad scope for users to input parameter values. A third broad distinction between models involves whether they "stand alone" or are part of a system of linked and interdependent models.

Structural differences between models affect the price paths they predict. Since intertemporal optimization models assume perfect foresight about

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[1] Much of the following discussion follows from Joseph Anderson, "Energy-Economy Modeling," ICF Incorporated, March 1983, pp. 9-11.

the future, they should predict smooth adjustments over time.[2] Recursive simulation models can produce sharply contrasting price paths with fairly dramatic oscillations. Sectors in these models behave according to current and past information only. Oscillations appear if they respond to this information at different rates. (For example, imagine a model in which higher prices may cause consumption sectors to cut back demand quickly but induce production sectors to increase supplies slowly. In this model, when additional supplies finally reach the market, demand may have been so sharply reduced that a sharp price drop results. This will encourage demand and discourage supply, sowing the seeds for a sharp price increase and another cycle later.)

Another structural difference that can affect a model's projections involves whether the model "stands alone" or is part of a system of linked interdependent models. In projecting oil price movements, models that are part of a system may capture economic feedback effects in ways that other models do not. (Consider the effects of disruptions in oil supplies, for example. Such developments not only tend to impose higher prices on direct oil consumers, they also tend to slow economic activity in other sectors. This slowdown in turn reduces oil demand, offering some counterpressure to upward oil price movement.) Other things equal, models that explicitly capture such effects -- as linked models are likely to do -- will project lower oil prices than models that do not.

Structural differences between models also affect their utility to model users. Some optimization models are built on the basis of engineering analyses of energy use and assume that, to reach desired objectives, society

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[2] Intertemporal optimization models do not always do so, however. Appendix B provides detail on this point.

will behave in ways the model specifies. By contrast, econometric/recursive simulation models frequently try to capture how society and energy markets actually behave. This distinction arguably makes the different kinds of models appropriate over sharply different forecast periods. Engineering/optimization models seem more appropriate for forecasting several decades away; econometric/recursive simulation models may offer greater insight for shorter-term forecasts. The former approaches essentially try to extrapolate what can be foreseen of technology. Although an enterprise fraught with hazard, such projection is more appropriate for the long term than are projections from econometric models, which so heavily weight the part of the recent past used to estimate their parameters.

Structural factors, therefore, permit one to make some broad observations about models' tendencies, strengths, and weaknesses. However, as may be seen in the following section, those factors alone cannot account for the variety of price paths that models project.

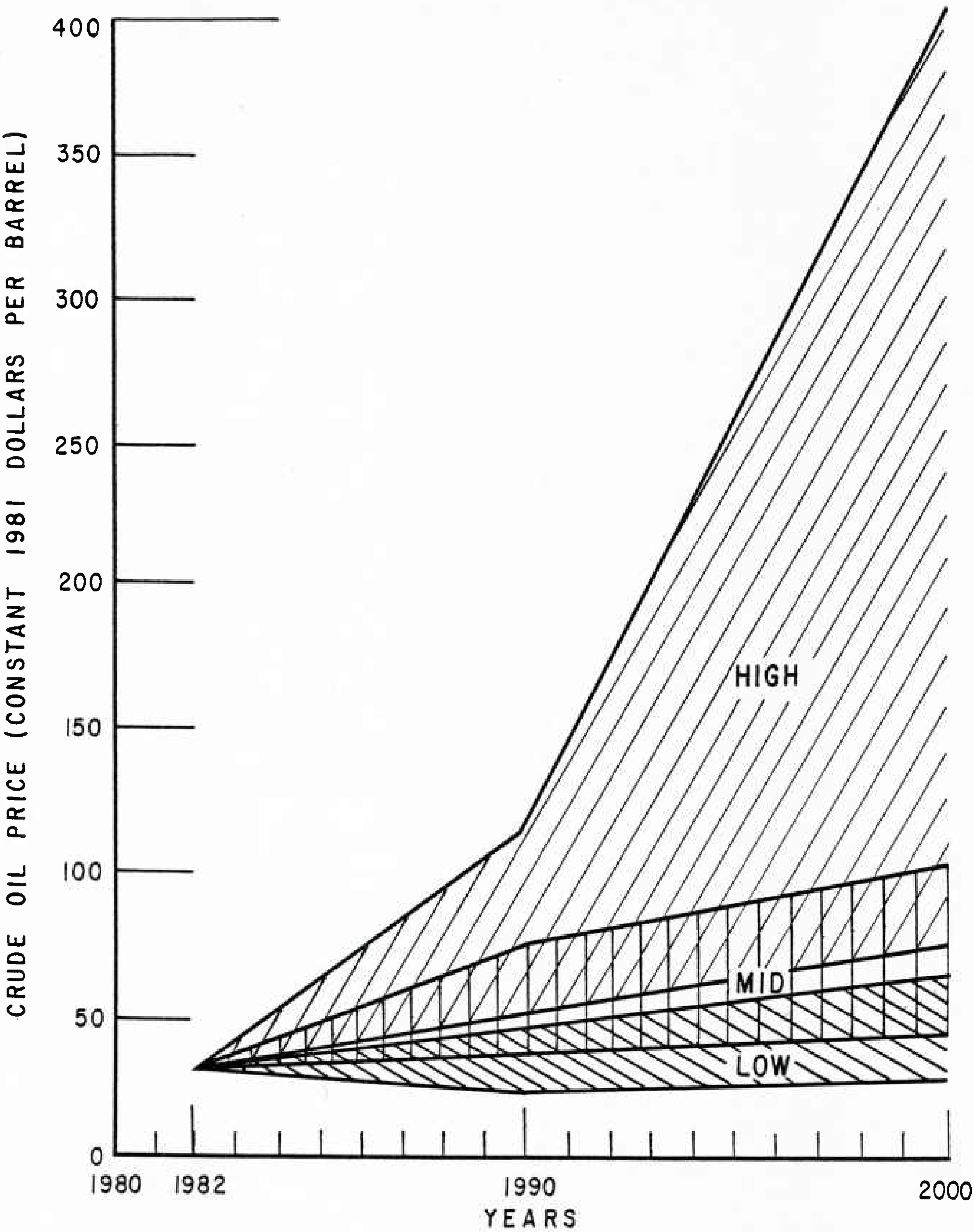
FORECASTS REVIEW

LMI reviewed world oil prices projected by 36 forecasts in the 1981-1983 period. Figure 3-1 summarizes these projections for the years 1990 and 2000.

Forecasters frequently project a number of price paths, each one corresponding to a different scenario of the energy future. For expository convenience, Figure 3-1 groups these paths into three categories, which are labeled "low," "mid," and "high." (The envelopes in Figure 3-1 are not themselves price paths; rather, they are constructed by connecting the 1981 price with the highest and lowest price projected for 1990 and for 2000 in each of the forecast categories.)

About one-third of the forecasts surveyed developed at least three price paths; the three envelopes in Figure 3-1 contain those paths. Another third

FIGURE 3-1 ENVELOPES OF 36 DISTINCT OIL PRICE FORECASTS FOR 1990 AND 2000



developed two price paths; the "high" and "mid" envelopes contain those paths. The remainder developed only one price path; that path fell within the "mid" envelope. In general, a substantial and enduring Mideast oil disruption is part of all the high-price scenarios but none of the mid- or low-price ones. Mid- and low-price projections reflect different assumptions about economic growth and about the sensitivity of energy demand to energy price.

The information summarized in Figure 3-1 will be of little use to DoD decision makers. Knowledge that the 1990 world oil price will range between $24 and $133 per barrel (1981 dollars) will not provide the policymaker with much help in making decisions. However, suppose DoD decision makers look at forecasts on a less highly aggregated basis; will greater detail provide greater insight? To answer this question, LMI examined a comparable set of forecasts provided by the Energy Modeling Forum (EMF).

Figure 3-2 displays the "reference case" price paths projected by seven recursive simulation models that were presented in the Energy Modeling Forum's 1981 "World Oil" Study. EMF cautions that these paths "should not be interpreted as our 'forecast' of the oil future as there are too many unknowns to accept any projection as a forecast."[3] Nevertheless, EMF describes its "reference scenario" as "representative of the general trends that might be expected."[4] For expository convenience, this discussion treats these price paths as forecasts.

EMF states that one purpose of its reference case is "to bring the models into as close an agreement as possible on basic assumptions."[5] That restriction gives some grounds for expecting that EMF reference case projections will

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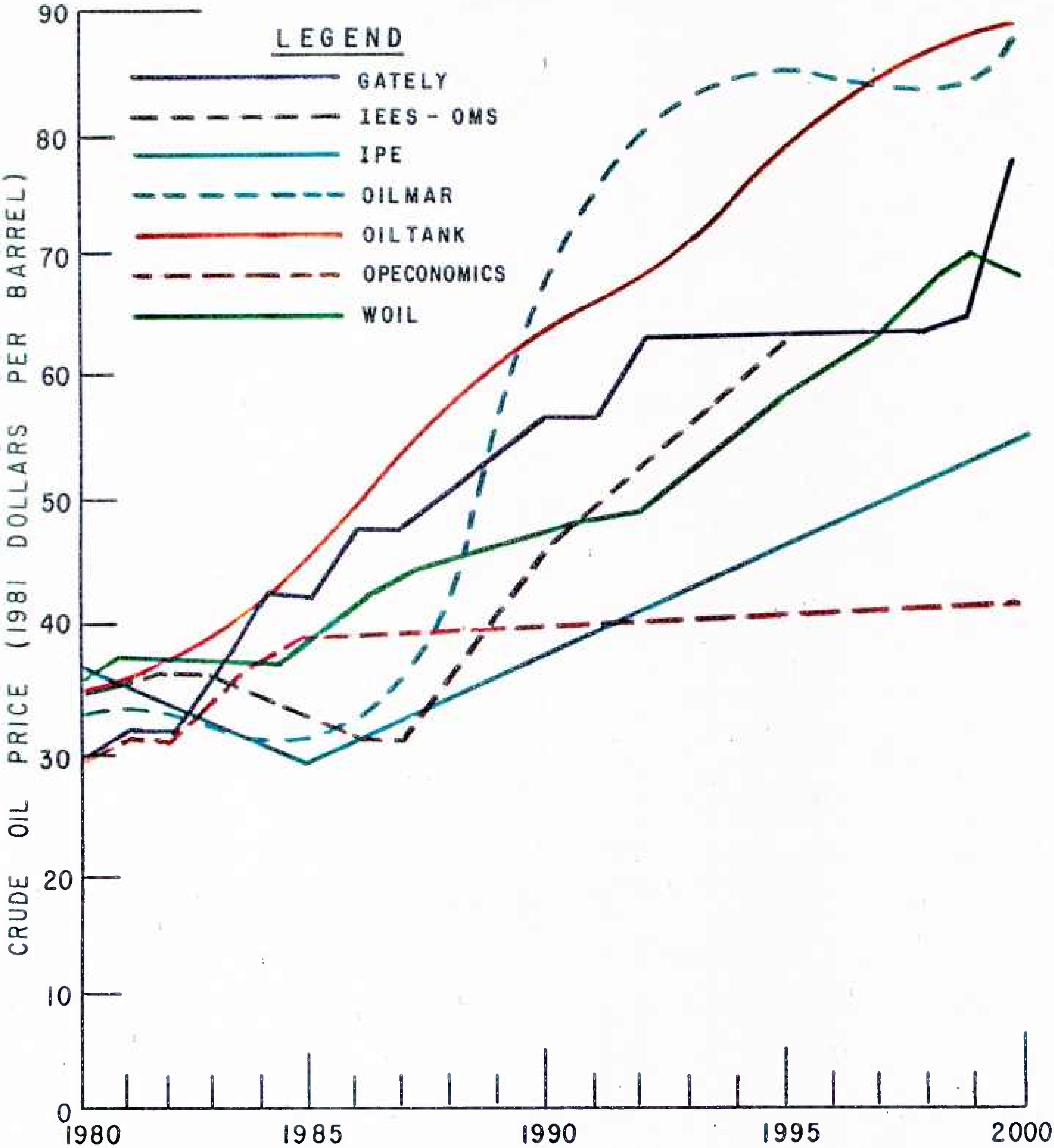
[3]Energy Modeling Forum, <u>World Oil Summary Report</u>, February 1982, p. 2.

[4]<u>Ibid</u>.

[5]<u>Ibid</u>., p. 22.

FIGURE 3-2 EMF WORLD OIL PRICE PROJECTIONS "REFERENCE CASE"/ RECURSIVE SIMULATION MODELS



SOURCE: ENERGY MODELING FORUM, WORLD OIL SUMMARY REPORT, FEBRUARY 1982

vary within tighter limits than the 36 projections summarized in Figure 3-1. EMF models fulfill this expectation to a degree. As Figure 3-2 shows, EMF reference case models predict oil prices between $37 and $66 per barrel in 1990, and between $39 and $88 per barrel in 2000.[6] These figures imply a range of $29 (78 percent) and $49 (126 percent) for 1990 and 2000, respectively. This range is tighter than the overall spread shown in Figure 3-1. However, it is still too broad to be useful, say, in determining the future worth to DoD of energy-saving research and development today.

Figure 3-2 contains some other insights for DoD policymakers. These points are especially striking when one considers that all seven price paths flow from models of a single structural type (recursive simulation) and that all seven reflect "as close an agreement as possible on basic assumptions." First, particular models are not necessarily "high" or "low" on a consistent basis. The International Energy Evaluation System-Oil Market Simulation (IEES-OMS) forecasts the lowest prices for 1983 and the highest prices for 1990-1993, for example. Second, models do not agree on whether price paths will be smooth or not; those that predict "kinks" do not agree on when they will occur or the direction of the price change the kinks portend. For these and other reasons, this study concludes that structural factors alone cannot account for the variety of price paths the models project.

The price paths of Figure 3-2 do agree that energy prices will move up over the long run. Given the fact of their origin in the 1980-1981 time period, that conclusion is not surprising; at that time, the energy forecasting community arrived at something close to a consensus on this point.

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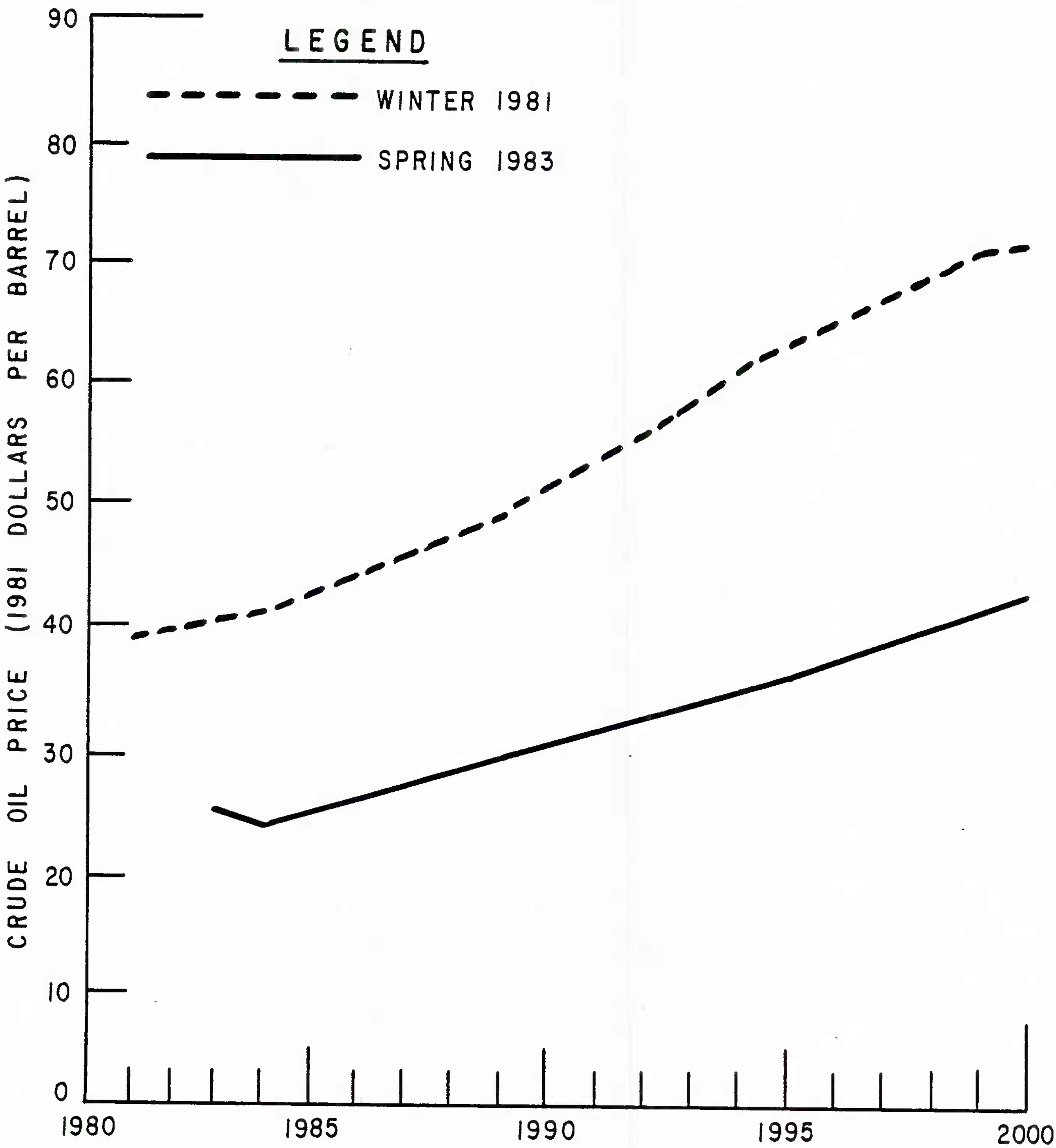
[6]EMF reference case intertemporal optimization models also fall within this range. For expository convenience, their price path projections are reported in Appendix B.

Whether that consensus still holds cannot be stated with certainty since EMF's world oil exercise has not been updated.

Figure 3-3 may shed some light on an answer. It displays two different oil price forecasts produced by a system of linked models owned by Data Resources, Inc. (DRI). The higher path reflects DRI's forecast of world oil prices in early 1981, and the lower one reflects DRI's May 1983 forecast. In both cases, DRI used econometrically specified parameters in a recursive simulation framework. Differences between the higher and lower paths do not reflect changes in the structure of DRI's system of linked models. Rather, they reflect changes in DRI's judgment about key inputs. At the very least, therefore, this means that DRI was once part of the "consensus" represented by the EMF price paths in Figure 3-2, but is no longer. Thus, one can safely conclude either that respected forecasters do not now have a consensus outlook or that they have one dramatically different from that of a few years ago. Neither possibility offers much comfort to DoD decision makers who want information that will help them reduce uncertainty about future events.

Recall that forecasts associated with the EMF reference case explicitly presume a scenario "representative of...general trends that might be expected." One can interpret DRI's forecasts similarly as representing a "most likely" estimate of how the future will unfold. The foregoing discussion shows that both sets of forecasts have features that limit their utility to DoD decision makers. However, suppose analysts compare these models under several alternative scenarios. Will the pattern of these models' projections across scenarios provide additional insight? Will several models' results for a particular scenario warrant increased DoD confidence in the robustness of these forecasts? Figure 3-4 helps answer these questions.

FIGURE 3-3 DRI WORLD OIL PRICE PROJECTIONS
1981 FORECAST vs 1983 FORECAST



SOURCE: DATA RESOURCES, INC.

Figure 3-4 compares price forecasts for the year 2000 across scenarios, and Table 3-1 summarizes key assumptions that define these scenarios.

Figure 3-4 warrants several observations. These models exhibit remarkable uniformity about the direction of price change in comparing one scenario with another. For example, all models produce lower-than-reference-case prices in the "oil demand reduction" scenario; all produce higher-than-reference-case prices in the "low demand elasticity" scenario. However, these models exhibit little uniformity in the magnitude of price change from one scenario to another. For example, the Opeconomics model's highest price prediction ($49 in the disruption and low demand elasticity scenario) is only 50 percent higher than its lowest ($33 in the low economic growth scenario). By contrast, the OILMAR model's highest price ($417 in the disruption and low demand elasticity scenario) is 731 percent higher than its lowest ($57 in the low economic growth scenario). Finally, these models exhibit greatest disagreement in their treatment of scenarios that involve an oil supply disruption or a low demand elasticity or both. (Note that the lines depicting each model's forecasts spread over a wide range in these scenarios and occupy a narrower range in other scenarios.)

Variations in forecasts are not arbitrary, of course. They exist for reasons that analysts can identify after a sufficiently detailed and exhaustive examination. However, the analysis summarized above suggests that such an examination requires potential model users to virtually become modelers themselves. In other words, these models do not require decision makers to make some broad judgments about the future and then inform them about what the judgments imply. Instead, they require decision makers to become minutely familiar with details before drawing any firm conclusions about why forecasts differ. This feature accounts for LMI's judgment that most of these models

FIGURE 3-4 EMF MODELS' FORECASTS OF WORLD OIL PRICE IN YEAR 2000 UNDER ALTERNATIVE SCENARIOS

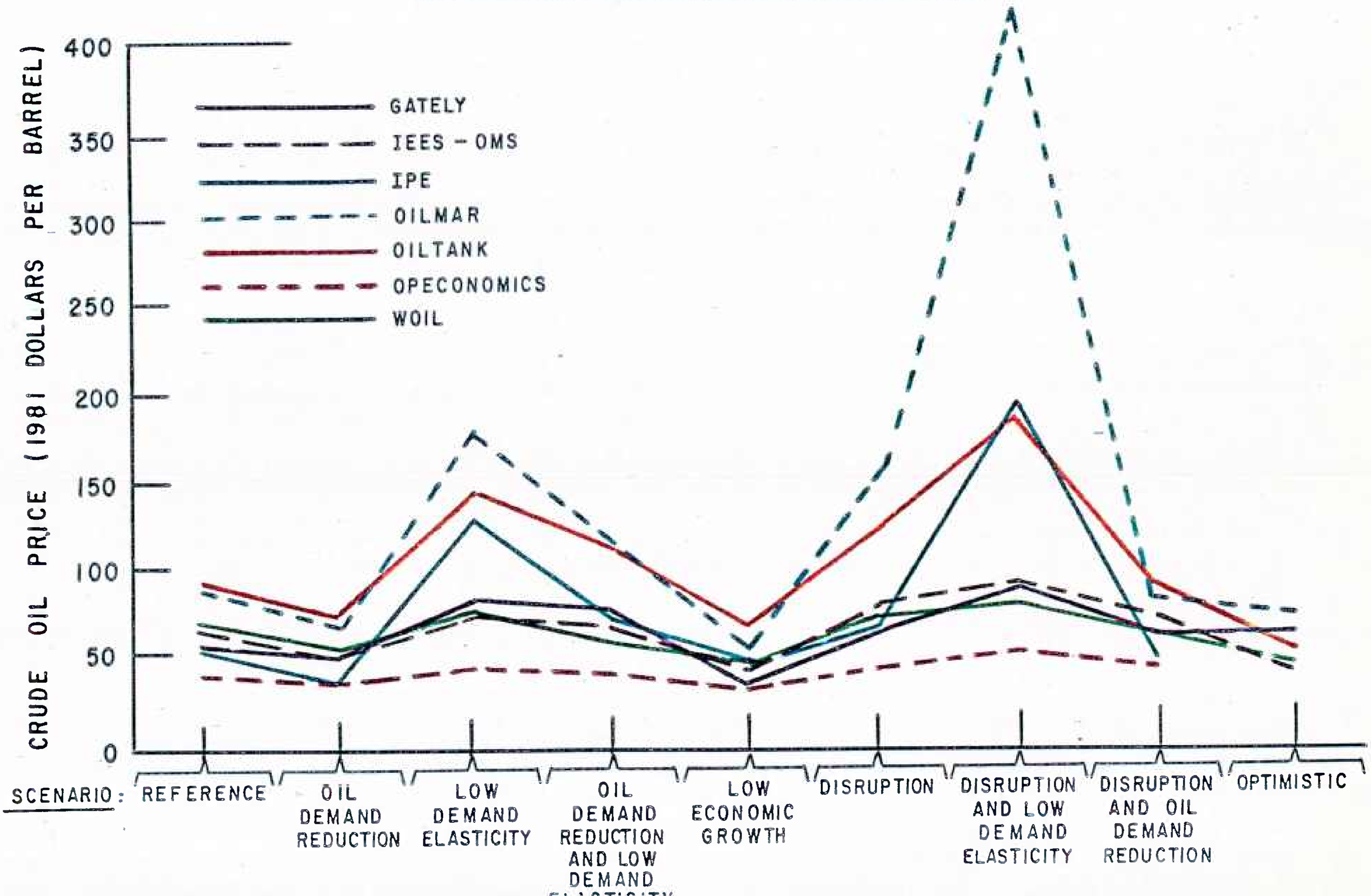


TABLE 3-1. EMF SCENARIO DESCRIPTIONS[a]

Scenario	Assumptions
Reference Case	OPEC production capacity constant at 34 million barrels per day (MMB/D); GNP growth rates of 3% and 5% in developed and less developed countries, respectively; demand elasticities[b] of 0.04 (short run) and 0.4 (long run).
Oil Demand Reduction	Aggressive import reduction program in the OECD[c]: 5 MMB/D by 1985; 10 MMB/D by 2000.
Low Demand Elasticity	Reduction in demand elasticities to 5/8 of reference case values.
Oil Demand Reduction and Low Demand Elasticity	Aggressive import reduction program in low elasticity world.
Low Economic Growth	Reduced GNP growth rates (2/3 of reference case values) throughout the world.
Disruption	Sudden and indefinitely continuing 10 MMB/D reduction in OPEC capacity beginning in 1985.
Disruption and Low Demand Elasticity	Ten MMB/D OPEC capacity reduction in low elasticity world.
Disruption and Oil Demand Reduction	OPEC capacity reduction of 10 MMB/D in presence of aggressive import reduction program.
Optimistic	Aggressive import reduction program; more availability of nonconventional energy; increased OPEC capacity.

[a]Energy Modeling Forum, op. cit., pp. 21-23.

[b]"Demand elasticity" is a measure of the responsiveness of demand to a change in price. For example, a demand elasticity of one implies a 1 percent decrease in quantity demanded as a result of a 1 percent increase in price.

[c]Organization for Economic Cooperation and Development. Member countries include Free World industrialized nations.

will not inform DoD's thinking about future price paths. This judgment follows from recognition that defense energy policymakers do not have time to become masters of detail for a range of alternative forecasting models.

MODELS THAT INFORM JUDGMENT

Two of the forecasting models LMI examined do, however, meet the study criterion that they inform decision makers' judgments about future price paths. In other words, these two models make predictions about future oil prices on the basis of some broad judgments about the future. The following paragraphs describe and analyze these models.

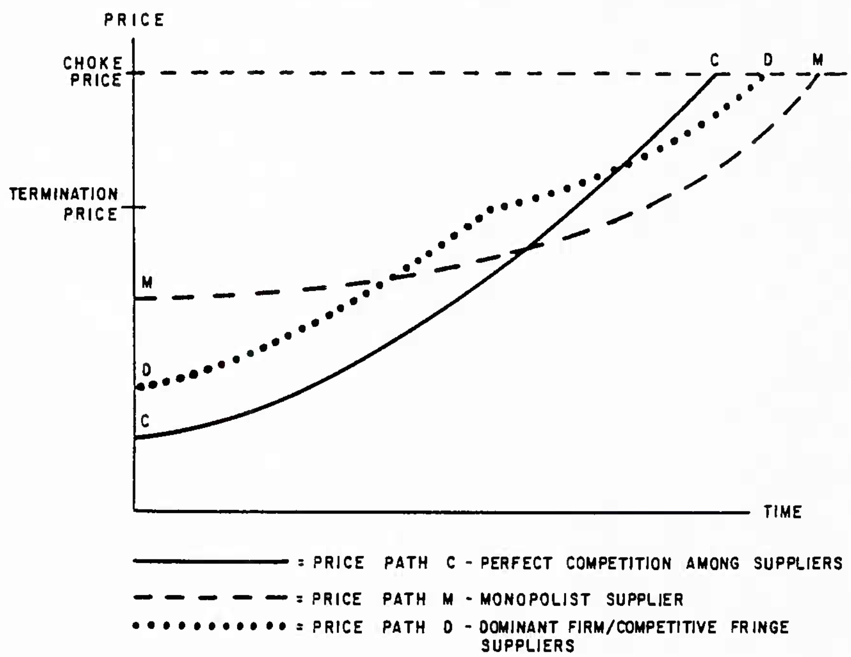
The Salant Model

Description. The "Salant model" applies the economic theory of exhaustible resources to the world oil market structure observed today and produces the price paths shown in Figure 3-5. Each of these three "price paths" depicts how a different market structure would cause the price of an exhaustible resource (crude oil) to change over time. Each presumes the existence of a "choke price" at which there would be no demand for the crude and makes several other assumptions. One such assumption is that production costs are negligible. A detailed accounting of other assumptions is not needed for present purposes; instead, a statement of the intuitively plausible "story" behind each path is provided.

Price Path C depicts how prices would move under perfect competition. They would rise from an initial price at the rate of interest until they reached the choke price. At that point, the world's oil inventory would be exhausted and the resource price would remain at the choke price. This path would occur because, in a perfectly competitive world, producers could not change prices by their production decisions. Nevertheless, they could make decisions about whether oil in the ground was worth more than money in

the bank. If a producer believes that next year's oil price will exceed the current price by more than the interest rate, he will defer production, and vice versa. Thus, expectations that prices will increase faster than the interest rate will lead to less production today and more tomorrow. This behavior will, in turn, lead to higher prices today and to lower prices tomorrow than would otherwise obtain. This behavior makes the rate of change between this year's price and next year's price tend toward the interest rate. Unless producers' expectations are systematically wrong, therefore, their desire to earn more than the interest rate will result in the price path moving up at that rate, over time. Of course, if a choke price exists, no producer will have an incentive to defer production after that price is reached. Thus, world inventories will be exhausted when the competitive price path reaches the choke price.

FIGURE 3-5 COMPARISON OF PRICE PATHS UNDER DIFFERENT MARKET STRUCTURES



Price Path M depicts how prices would change if a monopolist controlled the entire world oil inventory. Initially, the monopolist would set a

price <u>higher</u> than the competitively set price, and this price would be maintained by selling less than would be supplied under competitive conditions. Since the initial selling price is higher than the competitive price, the monopolist cannot increase the price at the interest rate and still sell off the entire world inventory before the choke price is reached. He therefore has to increase the price more slowly. Similarly, since he begins by selling smaller amounts than would be sold under perfect competition, he has to sell his inventory over a longer period than the inventory's life under perfect competition. In addition, he has to charge less at some point than would be charged under perfect competition, to induce consumers to buy the oil that they would have bought sooner, under perfect competition. For these reasons Price Path M begins higher than C but crosses below C before finally reaching the choke price.

Salant's analysis notes that neither perfect competition nor monopoly accurately characterizes today's world oil market. Instead, The Organization of Petroleum Exporting Countries (OPEC) oil producers (and/or the biggest producers within it -- Saudi Arabia, United Arab Emirates, and Kuwait) comprise a "dominant firm," with other producers forming a "competitive fringe." Certain producers are dominant because their production decisions can unilaterally affect the world price. However, "fringe" producers prevent this "dominant firm" from exercising full monopoly power. Salant's model incorporates this alternative view of market structure into exhaustible resource theory and produces Price Path D.

Several assumptions underlie Salant's model:

- both OPEC and non-OPEC producers have perfect knowledge of future demand;
- both seek to maximize the discounted present value of their revenue stream over the life of their resource;

- the dominant firm "takes the sales path of the competitive fringe as given and chooses a price path [supported by its production decisions] to maximize its discounted profits";[8] and

- each producer in the competitive fringe takes the price path as given and chooses a sales path to maximize the sum of discounted profits.[9]

Along Price Path D, both the dominant firm and the fringe initially produce oil. The dominant firm ensures that it sells at a rate that will permit its stocks to outlast those of the fringe producers.[10] Prices rise at the interest rate from the initial price until the fringe stops selling at what Salant calls the "termination price." This rate of increase occurs for reasons similar to those outlined for the perfect competition price path, C. If the dominant firm set a path along which prices increased at a greater or lesser rate, fringe firms would have an incentive to alter their sales paths. Thus, only if prices rise at the interest rate can the dominant firm take fringe sales as given.

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[8] Stephen Salant, "Exhaustible Resources and Industrial Market Structure," Journal of Political Economy, Vol. 84, No. 5, October 1976, p. 1080.

[9] Ibid. Paraphrase.

[10] Salant explains this behavior by disproving the alternative hypothesis, that the dominant firm would stop selling before fringe firms did so:

> For, suppose the ... [dominant firm] ... completed its sales before the competitors. Then the price path would rise at the rate of interest while the two sectors coexisted and would continue to rise at that rate after the ... [firm] ... stopped selling. Now, compare some early moment when the ... [dominant firm] ... is selling to some later moment when its sales are zero. When its sales are positive, its marginal revenue will be less than the price; when its sales are zero, its marginal revenue will be equal to the price (since it has no infra-marginal units on which to take losses). Since price is growing at the rate of interest, the marginal revenue would have to grow by more; but this would give the ... [dominant firm] ... an incentive to alter its strategy. Hence, in equilibrium, the competitors cannot continue selling after the ... [dominant firm] ... drops out.

Note that Path D begins at an initial price higher than Path C, and lower than Path M. This reflects the fact that the dominant firm has the market power to earn some monopolistic profits but that its power is limited by the fringe producers. Note also that Path D rises at a rate lower than the interest rate after reaching the termination price; hence the "kink in the curve" at this point. This change in price path slope reflects the fact that the dominant firm is effectively a monopolist over this interval. For reasons noted in discussing Path M, the dominant firm cannot continue to raise prices at the interest rate and still sell its entire inventory before reaching the choke price.

Assessment. This section discusses Salant's model in light of each assessment criterion specified in Chapter 1. For expository convenience, underlining highlights key words from each criterion.

The Salant model has been used elsewhere. Federal agencies and other organizations have relied on it to conduct simulations. Moreover, the model seems widely recognized as a significant theoretical advance. Accordingly, DoD decision makers can probably defend DoD's energy policy positions more knowledgeably and credibly if they enjoy some basic understanding of Salant's model.

Whether Salant relies on credible and evidence-testable assumptions warrants a mixed response. For example, the assumption that oil producers enjoy perfect foresight about future prices and/or future production behavior seems testable but not credible. However, if storage is costless, a single producer that correctly anticipated the profit-maximizing price path could bring about such a path. (The foresighted producer would shut in production and buy oil when quantities offered on the market were so large as to depress actual prices below the profit-maximizing level. Similarly, that producer

would increase production and sell oil when actual prices were too high. This behavior would lead actual prices to approximate those forecast by the Salant model.)

As a result of its perfect foresight assumption, Salant's model does not offer insights about disruptions. When changes in supply are foreseen, they do not exhibit the economic characteristics associated with disruptions. For similar reasons, Salant's model will not inform users regarding stockpiles' values.

The Salant model does inform DoD decision maker's judgments regarding future world oil prices. It does so by permitting users to relate their expectations about world market structure to alternative price paths. For example, if DoD decision makers believe that OPEC will display increased cohesiveness and internal discipline over time, they might anticipate a price path that remains above the competitive price path for the next few decades, rising at the real interest rate, until "fringe" reserves are exhausted. This projection would warrant continued DoD attention to the R&D implications of increasing real fuel costs. However, it hardly provides ground for crash programs or for making R&D investments from an energy emergency standpoint.

Finally, the Salant model can provide DoD decision makers with insights about the transition from conventional fuels to the "backstop" technology. A detailed description of how the model achieves this end is given elsewhere[11] and merely summarized here. Some people have argued that development of oil substitutes (e.g., gas from oil shale) will set an upper limit for world oil prices. Simulations of the Salant model indicate, however, that substitutes can have such an effect only if produced quickly and in

[11] For further discussion of this issue, see Stephen Salant, Imperfect Competition in the World Oil Market, Lexington Books, 1982, and especially the Introduction by Darius Gaskins.

massive quantities.[12] Thus, even if DoD decision makers anticipate problems with rising fuel costs over the next few decades, they should not assume that oil substitutes guarantee a price-moderating solution.

The Tussing Model

Description. Tussing provides a "qualitative model" of long-term oil markets based on historical analysis and economic theory.[13] He predicts that the real price of crude is unlikely to rise to the 1980-1981 price level for the rest of this century. The main point of his analysis is that the crude oil market is inherently cyclical: in the absence of a "price maker" capable of regulating supply to support a target price, oil prices will fluctuate, sometimes dramatically.

Tussing's analysis runs as follows.

- The oil market is inherently cyclical.
- Oil prices were stable for 40 years because the Texas Railroad Commission (TRC) regulated production.
- The 1973 and 1979 supply disruptions did not provide objective bases for more than a transitory spike in spot market prices. However, contract prices moved up to spot levels and stayed there as the result of a self-fulfilling misperception embodied in producer and consumer "psychology."
- OPEC did not really control prices in the 1970s; the Saudis had a chance to do so but lost it by sustaining too-high prices through too-low production.
- Prices must now come down, probably to somewhere between $10 and $18 per barrel.

Analysis. Historical patterns support Tussing's assertion that prices are cyclical. The cycle occurs because oil supply and demand respond to price change in the long run but not in the short run. Demand responds

[12] Ibid.

[13] Arlon Tussing, "An OPEC Obituary," The Public Interest, Vol. 70, Winter 1983, pp. 3-21.

slowly because it depends on stocks of capital goods, which change slowly. Supply also responds slowly because of long lead times for petroleum exploration and development. "This contrast between short- and long-term price-responsiveness inevitably fosters cyclical price behavior."[14]

The TRC began oil market intervention in the 1930s. At that time, the "rule of capture" governed oil production: oil belonged to whoever produced it. Oilmen therefore pumped crude as quickly as possible. This practice led to inefficiency because speedy extraction reduces the total amount a field can produce. The TRC regulated production so that all producers shared the revenue; the fields produced efficiently, and the market did not go through wild price swings. The TRC could achieve these goals because it had the legal authority to control the producers. (Louisiana passed legislation to comply with the system.) Because the United States, i.e., Texas and Louisiana, controlled the excess production capacity, the TRC controlled world oil supply. Three times in the 1950s and 1960s, the TRC and the oil companies had the option of raising prices in response to supply disruptions in the Middle East. In each case, they chose long-term stability instead of short-term profits.

As part of the system of control, the U.S. set oil import quotas, first voluntary then mandatory, to keep out cheap foreign crude. In the early 1970s, when the U.S. ran out of excess capacity, imports were increased and quotas were eliminated. The U.S. then lost its capacity to control the world oil price.

Tussing attributes the 1970s oil price path not only to U.S. loss of excess capacity but also to self-fulfilling misperceptions embodied in producer and consumer "psychology." In his view, these parties overreacted to

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[14] Tussing, p. 18.

relatively small supply changes and spot market movements. On the consumer side, a small number of large buyers saw rising spot prices as proof of a serious shortage; they therefore sought to build inventory. By so doing they increased demand and drove spot prices higher, thus inducing additional "socially irrational"[15] demand. Producers, on the other hand, saw rising prices as proof that oil in the ground was worth more than money in the bank. They therefore cut back on production. Spot prices did not return to contract levels, as had occurred in the past. Instead, contract prices rose to spot levels.

Tussing argues that OPEC did not "engineer" either of the price hikes in the 1970s. Both were begun by political events and relatively small supply disruptions; OPEC only voted to ratify price increases, which occurred for reasons noted above and were maintained by production cuts on the part of individual producers. OPEC lacked the power to maintain a price because it never had any legal authority over its 13 sovereign member nations. (The Texas Railroad Commission, on the other hand, enjoyed legal control over production and hence the ability to manipulate supply and support a target price.)

Tussing argues that Saudi Arabia could have played the part of the TRC because it had excess capacity, a small population, and small revenue demands. Unlike the TRC, which kept prices above free market levels but low enough to encourage demand, OPEC kept prices too far above free market levels. Consumer demand declined with a vengeance, and Saudi Arabia lost its opportunity to control supply and keep prices high.[16]

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[15] Ibid., p. 8.

[16] The Saudis can still push the world price down by stepping up their production. However, in Tussing's view, they cannot unilaterally push it up. In today's market, there is so much shut-in capacity that even a total Saudi production halt might well not push prices up.

The final part of Tussing's argument is that prices must go down, and he presents both supply-side and demand-side reasons to support his argument. On the supply side, Tussing notes that OPEC's market share has shrunk from 55 percent in 1974 to less than 31 percent in 1982. He is skeptical about whether its members have the ability to prorate production cutbacks and thereby maintain current prices, especially in view of the revenue requirements of their growing economies. Noting the 4 million barrels per day (MMB/D) increase from Alaska, the North Sea, and Mexico, he states that Mexico might increase its production by an additional 3 to 5 MMB/D by 1990. On the demand side, Tussing notes a change in the ratio of oil consumed per dollar of Gross Domestic Product (GDP). From 1960 to 1973, the oil/GDP ratio grew 1.3 percent per year. The ratio fell 1.5 percent per year from 1973 to 1979, and it fell 8 percent a year from 1979 to 1981. He asserts that price cannot stay high with demand falling that much. Moreover, Tussing suggests that the end of the recession does not necessarily mean a return to rising oil prices. When the recession ends, capital investment will increase and vehicles and equipment will be replaced even faster. He argues that industry will not abandon its energy efficient designs for equipment. Because there is a lag in the adjustment to price, the effects of the 1970s will be felt for a long time even if prices in the future were to fall as fast as they rose in the past.

Tussing expects that the "most stable and easily sustainable" price range will be somewhere between $10 and $18 (1982 dollars) for the rest of this century because coal and liquified natural gas provide a virtually price-competitive substitute fuel over this range. In addition, Tussing calculates an average world oil price of $13 per barrel (1982 dollars) over the past 110 years and finds it offers "some empirical support" for this price range.

Assessment. The Tussing model makes several assertions directly relevant to policy. In discussing these assertions, underlining highlights key words from the model assessment criteria.

Tussing's conclusion that oil markets are inherently cyclical warrants DoD interest in mechanisms to hedge against the harmful effects of dramatic price shifts. This conclusion also offers a qualitative insight about the likelihood of disruptions and informs judgment about the DoD-utility of oil stockpiles. Its rationale for why real crude prices are unlikely to return to the 1980-1981 level may inform DoD's judgment about future prices.

Tussing's model offers insights about the transition to backstop technologies. It suggests that the world will not simply "run out" of oil "out of the blue." Instead, Tussing's model suggests that rising prices will signal genuine scarcity in world oil reserves well before the fact.

Since Tussing's is a "qualitative model," one cannot unambiguously identify whether it is used elsewhere or the extent to which its predictions drive policy conclusions in and out of government although its appearance in a leading journal suggests some influence. However, DoD may wish to be skeptical about it. When Tussing's assertions are testable, some observers will doubt that they are credible.

The first liability of the Tussing model involves the range of its predictions. At one point in his argument, Tussing says that it is "barely possible" that certain events could "send prices soaring for a third time to levels signficantly above those reached in 1980-1981."[17] At another, he admits the possibility of a "descent far below the range of sustainable prices" so that "a worldwide 'energy crisis' would be with us again sooner or later." None of these observations are necessarily wrong, and all are

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[17] Tussing, p. 17.

consistent with his cyclical characterization of the oil market. However, they do raise some skepticism about the credibility of his "easily sustainable" predicted price range.

A second, and much more serious, problem with Tussing's model is his assumption that consumer and producer "psychology" overrode objective reality during the 1970s and resulted in higher-than-sustainable prices for long periods. The trouble with such an argument is that there is nothing to keep "psychology" from seizing on a small supply cutback to drive prices high again and keep them there. However, apart from the "barely possible" prediction mentioned in the previous paragraph, Tussing does not expect such an outcome. Instead, he expects prices in the \$10 to \$18 range because coal and natural gas can substitute for oil in this range. If this expectation is accurate, however, one wonders why prices are not already at this level because of the world recession. If the answer is the fact that the appropriate capital stock is not yet in place, how can Tussing be sure that psychology (and not inappropriate capital) accounts for the 1970s price hikes?

A third problem with the Tussing model is its assumption that the recession's ending will not keep prices up but will only accelerate a shift to more energy-efficient capital stock. This assumption may prove correct, but everything depends on expectations (or "psychology" as Tussing terms it). If consumers anticipate that, aside from occasional fluctuations, prices will range from \$10 to \$18 per barrel, they may well <u>not</u> continue the shift to more energy-efficient capital stock. In addition, tastes may shift back to more energy-intensive lifestyles in response to lower prices. In other words, if consumers agree with Tussing's price range prediction, a capital stock shift may not occur as Tussing predicts.

Taken together, these three problems with the Tussing model suggest that his predictions are extremely sensitive to his ideas about "psychology." DoD should not dispute this element's importance in oil market behavior. However, "psychology" is hard to measure and can change rapidly. This fact warrants some caution on the part of DoD policymakers should they decide to rely on Tussing's forecasts. Tussing's argument that oil markets are inherently cyclical does not rely on any particular premise about participants' psychology; his prediction of a $10 to $18 price range does. Accordingly, DoD decision makers may wish to shape policies that are robust in the face of oil market cycles but do not depend on $10 to $18 oil.

CONCLUSION: WHAT DOES ANALYSIS OF LONG-RANGE FORECASTS TELL DoD?

This review of long-range forecasts bears some policy implications for DoD.

First, DoD decision makers must clearly understand the limitations of long-range forecasts. DoD cannot base policy on a consensus among forecasters, because no such consensus exists. Different forecasters make dramatically different predictions. Nor can DoD decide to "go with" a single forecaster to form consistent policies because the same forecaster may change his predictions sharply from one year to the next. Finally, DoD often cannot choose sound structural assumptions and unambiguously determine an implied price path. In fact, many models are so complex that users must immerse themselves in detail to the same extent that modelers do. This circumstance reduces models' utility: instead of helping DoD decision makers think clearly about broad issues, these models invite focus on details.

The second policy implication is that the Salant and Tussing models warrant DoD attention. Both permit decision makers to make some key judgments

about the future and to draw informative conclusions regarding price paths. Some DoD-relevant examples are noted below.

Salant's model points out that, barring discovery of a cheap and plentiful substitute, oil prices will eventually rise because oil is a finite resource. However, prices need not go ever higher from now on. In fact, oil prices may fall over some future period. Salant shows that world oil market structure will prove a key factor in shaping whatever course oil prices take. Therefore, DoD decision makers may wish to make broad judgments about future market structure as a basis for particular energy policy choices.

Salant's model can also inform DoD's judgments regarding the utility of shale oil or similar programs as a means to make the transition from conventional petroleum. It counsels caution about expectations that such programs will set a ceiling on oil price and thereby permit DoD to avoid eventually rising prices for conventional fuels.

Tussing's model makes two contributions that can help DoD's approach to energy policy. One contribution is Tussing's prediction of an eventual price drop to the $10 to $18 per barrel range. Analysis in this study suggests that Tussing based this prediction not only on his assumptions about the costs of replacement fuels but also on his assumptions about "psychology" (i.e., expectations). Therefore, DoD should not accept Tussing's prediction unless it accepts both types of assumptions.

Tussing's second contribution is his observation that the world oil market is inherently cyclical. This prediction cautions against efforts to find perfect forecasts that will keep DoD from being surprised in the future. Instead, this prediction argues for DoD efforts to cope with the surprises that will occur. The following chapters examine models that will help DoD in such efforts.

4. DECISION ANALYSIS APPROACHES

This chapter introduces two models -- the Teisberg model and the Saaty model -- that address the uncertain future of petroleum markets. The Saaty model explicitly projects future oil prices; the Teisberg model was designed for other purposes but projects the impact of stockpile drawdowns on future prices. Both models embody analytical techniques developed for use in decision making, not forecasting. Therefore, each is a "decision analysis" model. In virtually all other respects, however, these models differ sharply.

LMI's analysis of these models led to several conclusions. Neither model will prove helpful for forecasting future oil prices. However, the Teisberg model meets two of this study's assessment criteria so solidly that it is commended to DoD's attention. It can help estimate stockpiles' values and it offers insights about supply disruptions. The Saaty model offers a framework for projecting future oil prices, but the forecasts derived from it will come at a considerable cost in DoD decision makers' time. In LMI's judgment, certain problems with the Saaty model imply that its forecasts do not justify this cost.

This study's treatment of these models reflects the conclusions just stated. This chapter does not discuss the Saaty model further; it is described and analyzed in detail in Appendix C. This chapter discusses the Teisberg model, and some supporting detail is also given in Appendix C.

THE TEISBERG MODEL

The Teisberg model was <u>not</u> designed for use in making oil price forecasts. Nevertheless, LMI decided to include it in this study as a result of preliminary judgments on three points.

First, LMI judged that the Teisberg model might assist in defining an oil price path by showing the effects of optimal Strategic Petroleum Reserve (SPR) acquisition and drawdown decisions on oil prices during disrupted and nondisrupted periods. It could thereby inform judgment today about an uncertain petroleum future because SPR decisions can dramatically reduce the size of price shocks that the U.S. economy and DoD would otherwise face.

Second, LMI judged that the Teisberg model might help in estimating the value of petroleum stockpiles in excess of their cost. Such estimates can inform DoD decision making in two ways: (1) they can help DoD decide whether to build a crude reserve earmarked for defense purposes and how to argue for such an action; and (2) they can help DoD understand one way in which DOE will define the cost that the country pays for DoD use of the nation's SPR.

Third, LMI judged that the Teisberg model might help in defining the kind of acquisition and drawdown policy that will best meet DoD's requirements. Optimal policies are sometimes intuitively obvious and sometimes exactly counter to intuition. The model can affect DoD's decisions by specifying which policies fall into which category. This chapter provides an example of how the model does so under "Model Assessment."

LMI's analysis confirms the second and third judgments but not the first. Comments explaining this assessment of the Teisberg model follow a description of the model's structure, operation, and output.

Model Structure

Assumptions. The Teisberg model requires an extensive set of assumptions. Three kinds of inputs are especially important to understanding how it works.

First, the model requires the user to specify the price path he expects the world oil market to follow if supply disruptions do not occur. It

also requires him to specify the price and arrival time of the "backstop" (i.e., the technology that will provide the perfect substitute for oil).

Second, the model requires the user to define the slopes of the supply curves anticipated in each of five different "market states," each representing different conditions in the world oil market. In the model version discussed here, these market states represent anticipated conditions ranging from a slack market (in which buyers can demand an additional 333,000 barrels per day without increasing the world price) to a major disruption (in which net supplies are suddenly reduced by 12 MMB/D and in which additional demand dramatically increases the world price).

Third, the Teisberg model requires a decision maker to make subjective estimates of the likelihood, depth, and duration of oil supply disruptions in the future. Economic theory does not predict when future disruptions will occur, how long they will last, or how deep they will be; these disruption characteristics are functions of political events. As such, a decision maker's judgments about these characteristics are indispensable for making rational choices. The Teisberg model incorporates such judgments by requiring that users specify the percentage of time that they expect the world oil market to spend in each of the five market states over the next 20 years. The model also requires a subjective estimate of the expected length of a major disruption should one occur. Given these estimates, it is possible to compute a "transition matrix," which is in many ways the heart of the model.

Two examples of such matrices are provided in Table 4-1. Each matrix specifies the probability of moving to each of the five possible market states in Time Period p+1, given that one is in one of those states in Period p. To illustrate, consider the "optimistic" transition matrix. It reflects expectations that only 1 percent of any prolonged time period will be

TABLE 4-1. EXAMPLES OF TRANSITION MATRICES

Optimistic - Expected Length of Major Disruption is Three Months

INITIAL MARKET STATE	PROBABILITY OF MOVING IN THE NEXT MONTH TO THE FOLLOWING MARKET STATE:				
	Slack	Tight	Minor Disruption	Moderate Disruption	Major Disruption
Slack	0.9723	0.0078	0.0182	0.0013	0.0004
Tight	0.0238	0.9445	0.0238	0.0048	0.0030
Minor Disruption	0.0559	0.0026	0.9168	0.0139	0.0108
Moderate Disruption	0.0443	0.0000	0.0256	0.9168	0.0143
Major Disruption	0.1928	0.0000	0.1361	0.0043	0.6668
AVERAGE TIME SPENT IN EACH MARKET STATE	64%	10%	20%	5%	1%

Pessimistic - Expected Length of Major Disruption is Six Months

INITIAL MARKET STATE	PROBABILITY OF MOVING IN THE NEXT MONTH TO THE FOLLOWING MARKET STATE:				
	Slack	Tight	Minor Disruption	Moderate Disruption	Major Disruption
Slack	0.9445	0.0308	0.0130	0.0065	0.0052
Tight	0.0217	0.9168	0.0247	0.0195	0.0173
Minor Disruption	0.0217	0.0217	0.9168	0.0087	0.0312
Moderate Disruption	0.0260	0.0000	0.0087	0.9168	0.0485
Major Disruption	0.1083	0.0000	0.0563	0.0022	0.8332
AVERAGE TIME SPENT IN EACH MARKET STATE	40%	20%	20%	10%	10%

characterized by a major oil supply disruption and that the length of such a disruption would be 3 months in the (highly unlikely) event that it should occur. Given these expectations, the probability of moving into a major disruption from a slack market state is 0.0004, the probability of remaining in such a disruption once there is 0.6668, and so on.

In addition to the assumptions just described, the Teisberg model relies on two pieces of analytical apparatus that are not universally understood: (1) the concept of social surplus and (2) decision trees.

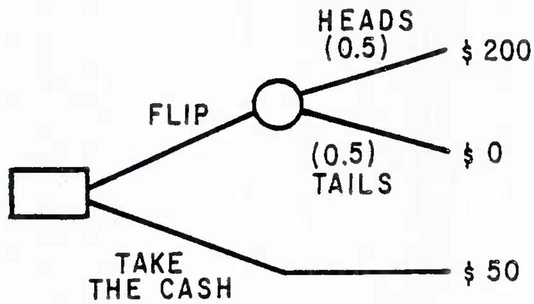
Appendix C explains the economist's concept of social surplus in some detail. For present purposes, social surplus merely represents one way to measure the cost to society of oil supply disruptions and the benefits to society of using stockpiles to reduce the price shocks associated with those disruptions.

Decision trees warrant more detailed explanation in this chapter because they are critical to understanding how the Teisberg model works. Accordingly, the following section presents such a discussion.

Decision Trees. Use of decision trees can conveniently be introduced by hypothetical example. Suppose a contest winner is offered a choice between two alternatives. He can take \$50 as his prize, or he can flip a fair coin. If the coin comes up "heads," he wins \$200; if the coin comes up "tails," he wins nothing. Figure 4-1 depicts that choice in decision-tree notation.

In Figure 4-1, the individual's choice between flipping and receiving \$50 with certainty is depicted by the square termed a "decision node." If he decides to flip, the expected value of his choice is apparent at the circle, or "chance node": it is 0.5 (the probability of flipping heads) times \$200 plus 0.5 (the probability of flipping tails) times \$0, or \$100. If the

FIGURE 4-1 DECISION-TREE NOTATION

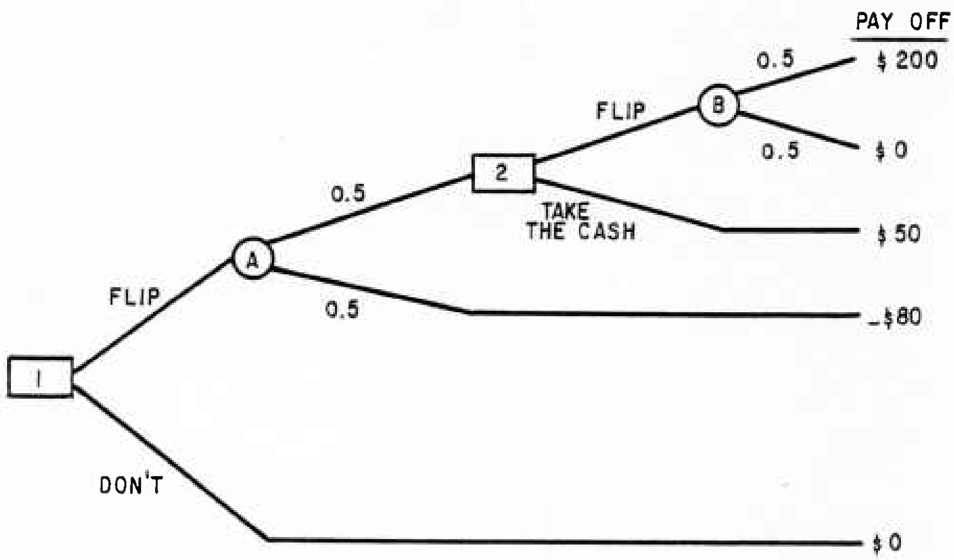


individual seeks neither to take risks nor to avoid them (i.e., if he is "risk neutral"), he will decide to flip the coin since the expected value of that choice is $100. Moreover, he would be willing to pay up to $100 to be offered this choice. In decision-tree terms, the expected monetary value (EMV) of being at the decision node depicted above is $100.

Now suppose the same individual is told that he can flip another coin. Heads will land him at a decision node identical to the one just described; tails means he has to pay $80. The individual's choices can then be depicted as shown in Figure 4-2.

By the logic described above, the EMV of being at Decision Node #2 is $100. Thus, the EMV of being at Chance Node A is [0.5 x $100] plus [0.5 x (-$80)], or $10. If the individual chooses actions on the basis of their expected value, he will follow the recursive procedure described so far. In decision-tree jargon, he will "average out and fold back" to determine the expected value of choosing to flip at Decision Node #1 or choosing not to. After doing so, a risk neutral individual will choose to flip at Decision Node #1. If he gets heads, moreover, he will choose to flip again (and not take the $50) at Decision Node #2.

FIGURE 4-2 TWO RELATED CHOICES IN DECISION-TREE NOTATION

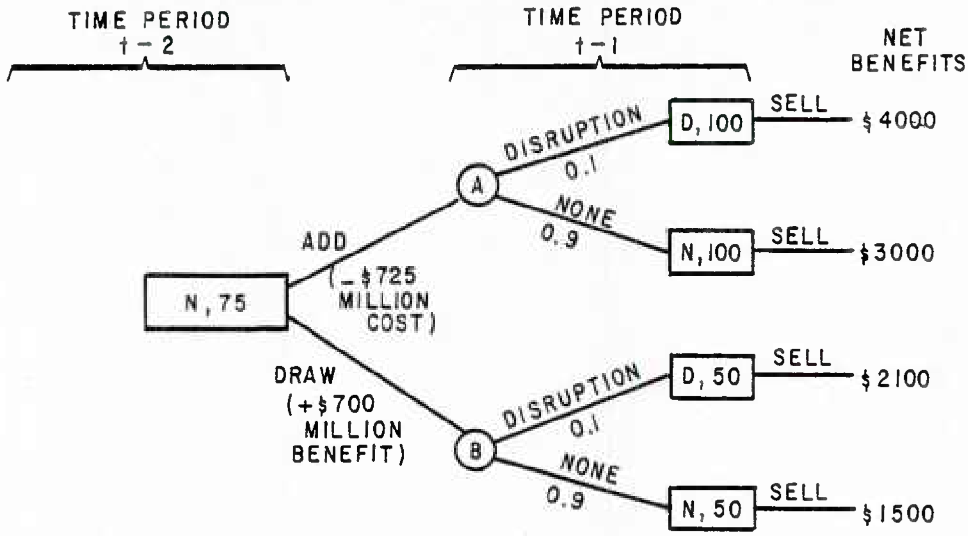


Model Operation

Solution Procedure. The Teisberg model's recommendations about acquisition and drawdown policy use a recursive solution procedure similar to the one just described. After all, the individual's choices in the example just given resemble the government's choices in making SPR acquisition and drawdown decisions. Both decision makers must make choices that depend on uncertain future events and also on subsequent choices. To see this, consider Figure 4-3.

Figure 4-3 depicts a decision tree "branch" from a radically simplified version of the Teisberg model; all costs reflect discounted present values. In this example, the government is in a nondisrupted market state at Time Period t-2, with an SPR containing 75 million barrels of oil. (Hence the decision node's label is [N,75].) The government must choose between adding 25 million barrels to the SPR and selling off the same amount. (The actual model considers all possible acquisition and drawdown choices; for

FIGURE 4-3 SIMPLIFIED "BRANCH" OF TEISBERG MODEL DECISION TREE



simplicity's sake only two are shown here.) The costs of adding are $725 million, and the benefits from drawing down are $700 million. [The actual model would compute these values by calculating the costs of storing oil, the costs (or revenues) of oil purchases (or sales), and the changes in consumer's surplus that result from any consequent movement in the world price.] Whether the government adds or draws, there is one chance in ten that a disruption will occur and nine chances in ten that it will not. However, the government cannot determine the right choice for Time Period t-2 without knowing the choices it will make for later time periods, such as Time Period t-1. Thus, the solution for the U.S. government requires "averaging out and folding back" using the payoffs specified at the very end of the tree, just as was done in solving Figure 4-2.

Input assumptions mentioned earlier make it easy to define payoffs at the end of the tree, such as those depicted as net benefits in the extreme right hand column of Figure 4-3. (On the basis of a price path input by the user, the model "knows" the price of oil in the terminal time period, t. The

model assumes that a "backstop" oil substitute will be available in the next time period, t+1, at a specified price. As a result, the government will not need the SPR in Time Period t+1 and will sell the SPR oil at Time t whether or not there is a disruption at that time. By multiplying the price at Time t by the SPR's size, therefore, the model can calculate the "payoff" for every possible SPR size at Time t.) Given those payoffs, recursive calculation can be used to determine the optimal choice at decision node [N,75].[1] Similarly, the Teisberg model permits determining the optimal choice today given the assumptions about the backstop price 20 years in the future.

Output. Table 4-2 is a sample of model output. It summarizes SPR drawdown rates recommended by the Teisberg model for a major disruption occurring in 1990 when the SPR contains 695.8 million barrels. "Optimistic Probabilities" and "Pessimistic Probabilities" refer to the dramatically different views of the future summarized by the transition matrices in Table 4-1. The message for DoD from Table 4-2 is that, over this broad range of expectations about the future, DOE's optimal strategy is to draw down the

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[1]These recursive calculations would go as follows. Since the government knows it will sell in Period t, it can calculate the expected value of selling 100 million barrels vs. selling 50 million barrels at that time. If a disruption occurs, the net benefits of a 100 million barrel sale (in revenues earned and social surplus losses avoided) will be $4 billion; those of a 50 million barrel sale, $2.1 billion. (Selling the first 50 million barrels brings greater benefits than the second 50 million.) If a disruption does not occur, benefits will be $3 and $1.5 billion, respectively. Thus the expected value of being at Chance Node A is (0.1 x $4 billion + 0.9 x $3 billion) = $3.1 billion; that of being at Chance Node B, (0.1 x $2.1 billion + 0.9 x $1.5 billion) = $1.56 billion. However, getting to "A" will cost the government $725 million since it incurs purchase and storage costs in buying oil and social surplus losses by driving up the world price. By contrast, Figure 4-3 shows that getting to "B" will bring $700 million in benefits (earnings on crude sales and social surplus increases due to a fall in world prices). The expected value of adding oil at [N,75] is therefore ($3.1 billion - $0.725 billion) = $2.375 billion; that of drawing oil down is ($1.56 billion + $0.7 billion) = $2.26 billion. Given the assumptions of Figure 4-3, therefore, the optimal decision is to add oil in Time Period t-2.

TABLE 4-2. TEISBERG MODEL MONTHLY SPR DRAWDOWN RECOMMENDATIONS
(Millions of Barrels)

[Assumes 12 Million Barrels/Day Disruption in 1990]

	Optimistic Probabilities		Pessimistic Probabilities	
Month After Start of Disruption	3-Month Expected Length	6-Month Expected Length	3-Month Expected Length	6-Month Expected Length
Start	125.0	125.0	125.0	120.8
1	125.0	125.0	125.0	108.3
2	125.0	112.5	112.5	95.8
3	125.0	95.8	100.0	87.5
4	100.0	83.3	87.5	79.2
5	66.6	66.7	70.8	66.6
6	29.2	50.0	50.0	54.2
7	0	29.2	25.0	41.7
8	0	8.3	0	29.2
9	0	0	0	12.5
Total Drawdown	695.8	695.8	695.8	695.8
Amount of Oil Remaining in SPR	0	0	0	0

Source: U.S. Department of Energy

entire SPR. Thus, DoD can anticipate dramatically lower prices than it would otherwise face if it believes politicians will permit DOE to follow this strategy.

Assessment of the Teisberg Model

Consideration of the Teisberg model in the light of the specified assessment criteria provides a broad understanding of its utility to DoD. The following assessment explicitly considers six criteria. (Since the model makes no predictions about the transition to 'backstop' technologies, that

criterion is not treated.) For convenience, each section begins with an abbreviated statement of the criterion it addresses.

Used Elsewhere? Yes, with qualifications. The DOE policy office uses the Teisberg model in the sense that it keeps it up and running and frequently relies on it for purposes of policy analysis. (For example, the Teisberg model is the principal tool used when DOE negotiates with OMB -- on analytic grounds -- regarding the fill rate for the SPR.) On the other hand, political leaders frequently make SPR decisions for which it is hard to see the model lending analytical support. (Currently, for example, the Administration is seeking to pare the deficit by reducing the SPR fill rate to 145,000 barrels per day. Over a broad range of assumptions, the model recommends a much higher fill rate.)

Credible Assumptions? Yes, with qualifications. On one hand, the model permits the decision maker to specify the long-term price path expected in the absence of disruptions; it also accepts the decision maker's own estimates of the likelihood, depth, and duration of future supply disruptions. These estimates are, by definition, credible to the decision maker. On the other hand, the model assumes that decision makers are risk-neutral and will always choose the policy alternative associated with the highest expected monetary value. These assumptions may prove unwarranted.

Recall that risk neutrality means that a decision maker neither seeks risk nor seeks to avoid it. That assumption makes the modeling problem more tractable, but it may not accurately characterize the decision making style of U.S. political leaders. In the real world, it is easy to imagine their being risk seekers at one time and risk averters at another. In the current oil glut, for example, political leaders seem to accord relatively low priority to preparations for possible future oil supply disruptions. To the

extent that they thereby fail to take out insurance commensurate with the expected value of future losses, their behavior can be characterized as "risk seeking" even if they would never describe themselves in such terms. On the other hand, if a serious supply disruption were to develop over the next six months, it is easy to imagine many of these same individuals becoming extremely averse to risk and refusing to draw down the SPR despite expected net benefits from so doing.

Evidence-Testable Assumptions? Yes and no. Consider estimates of the sensitivity of demand to price changes, for example. Econometricians continually attempt to come up with ratios reflecting the percentage change in demand that would follow from a given percentage change in price. Such estimates -- termed "elasticities" -- may well be entirely believable for price changes within the range of historical experience. However, there is no compelling reason why elasticities computed for a price rise from $16 to $32 should necessarily hold for a rise from $32 to $100, and there is no historical evidence on which to base more accurate elasticities with any confidence.

That all Teisberg model assumptions cannot be compared with empirically verifiable data should neither be surprising nor used as a basis for rejection of the model. Many other forecasting models necessarily share this characteristic. This criterion remains important, however. In using elasticities, for example, the Teisberg model at least relies on assumptions that many energy analysts use and are continually attempting to refine. Other models rely on assumptions that no one else uses or attempts to quantify. As a result, such assumptions are less subject to informed scrutiny and may, therefore, be less robust.

Inform Judgments About Future Price Paths? No. The Teisberg model shows that, when used properly, the SPR will dramatically reduce the costs of disruptions to the U.S. economy. However, output from the model version currently programmed on the DOE computer does not explicitly show the dollar-per-barrel decrease in prices that would follow from an SPR draw. Such information is implicit in the computer program -- otherwise it could not make the consumer surplus savings estimates needed to compute the benefits of an SPR drawdown. However, the program would have to be altered to make these price data an explicit output.

Even after such alteration, the Teisberg model would not provide a price forecast in the sense that the models described in Chapter 3 do. This is because in the Teisberg model many paths are possible for each set of input assumptions needed to run the model. Accordingly, LMI does not recommend use of the Teisberg model as a forecasting tool. In short, this analysis warrants rejection of the first of the three preliminary judgments which originally aroused LMI's interest in the Teisberg model.

Help Estimate Stockpiles' Value? Yes. The Teisberg model has been used to estimate the value of placing another barrel of oil in the SPR, in excess of the cost of doing so. (The model showed this value to be $36 if one is optimistic, i.e., believes that a disruption in excess of 6 MMB/D will never occur and that price shocks will be relatively minor if smaller disruptions do occur. By contrast, the model showed this value to be $78 if one makes pessimistic judgments, e.g., a 10 percent chance of a 12 MMB/D disruption.) Knowledge of such estimates and their sources may prove useful to DoD. For example, such knowledge would help DoD anticipate possible arguments (from Congress or DOE or elsewhere) that DoD demonstrate equally large benefits per barrel for any reserve it advocates for defense purposes.

Despite their utility on grounds just described, the Teisberg model's stockpile-value estimates cannot be directly applied to a dedicated DoD reserve. The Teisberg model assumes that the SPR will be drawn down in economic emergencies and auctioned to the highest bidder. A DoD reserve, by contrast, might be drawn down only for military emergencies and would most likely be allocated not auctioned. Thus, drawing down DoD reserves might well reduce consumer surplus losses that would otherwise occur, but it would not bring benefits commensurate with those from drawing down the SPR an equal amount.

Offer Insights About Disruptions? Yes. The Teisberg model offers such insights by defining the kind of acquisition and drawdown policy that best meets DoD's requirements. Optimal policies are sometimes intuitively obvious, but sometimes they are exactly counter to what intuition might suggest. The model can enlighten DoD's decisions by specifying which policies fall into which category. For example, consider the perspective of a DoD decision maker who is relatively pessimistic about the likelihood, depth, and duration of oil supply disruptions. Intuition suggests that, in a slack market, such an individual would recommend vigorous oil purchases to build a large SPR; not surprisingly, the Teisberg model recommends the same thing. Now consider the same decision maker during an oil supply disruption occurring when the SPR is relatively small. Intuition suggests that because he is pessimistic about future disruptions and because there is so little oil in the SPR, the decision maker should recommend against drawing down the SPR even though doing so will increase petroleum availability to DoD. The Teisberg model flatly contradicts this recommendation; for both optimistic and pessimistic expectations over a wide range, it shows that the optimal policy during disruptions involves rapid drawdown of the bulk of the SPR. Such a drawdown

would benefit not only DoD but the entire nation as well. By providing this kind of sound but counterintuitive result, the Teisberg model offers insights about disruptions that can enhance the quality of DoD's supply assurance policies.

CONCLUSION: WHAT DO DECISION ANALYSIS MODELS TELL DoD?

The foregoing analysis suggests that decision analysis models do not tell much about the future oil price path. Nevertheless, the Teisberg model can help DoD shape policies to deal with the uncertain petroleum future.

The Teisberg model provides persuasive evidence that big benefits accrue from stockpiling. However, it also shows that those benefits depend not only on the stockpile's size but also on the way it is drawn down. These points bear important implications for DoD energy policy. DoD can help the nation by devoting some of its budget to building oil stockpiles. However, some people will argue that an independent DoD stockpile only makes sense if it is governed by a different drawdown policy than that of the Strategic Petroleum Reserve. However, if DoD's drawdown policy differs, critics in and out of government may oppose a Defense Petroleum Reserve on grounds that it provides smaller benefits per barrel.

The Teisberg model can help DoD even if a Defense Petroleum Reserve is never built. Specifically, it gives DoD analytical support to argue for a rapid SPR drawdown in a future disruption. Such a drawdown must be made by auction or the Teisberg model's benefit estimates will not apply. Therefore, DoD should secure the authority to pay spot market prices so that it can reap the benefits of such an auction.

5. DISRUPTION FORECASTS

This chapter defines "disruption forecasts" and shows why disruptions cannot be ignored in long-range oil price forecasts. It then reviews three forecasts, noting how the associated policy prescriptions affect DoD energy policy, and evaluates the predictions of those forecasts. In the final section, the value of disruption forecasts to DoD policymakers is discussed.

Like long-run forecasts, disruption forecasts are frequently based on both a qualitative model (a systematic set of propositions about what elements are important in disruptions and about how they interact) and a formal mathematical model. This chapter confines itself to examining qualitative disruption forecasts.

DISRUPTIONS AND THE LONG-RUN PETROLEUM FUTURE

Despite their many differences, virtually all long-range forecasts agree on several propositions. They all tend to predict that for the next few decades -- and perhaps for much longer -- petroleum is going to be the world's primary source of what DoD terms "mobility energy." They also seem to agree that the cheapest oil to produce will probably continue to be found in politically unstable parts of the world. In addition, they all give grounds for judging that the economic health of consuming countries will remain vulnerable to supply cutbacks. Finally, they tacitly concede that such events cannot be predicted on economic grounds and may occur for political reasons at any time.

Taken together, the foregoing propositions warrant the conclusion that no survey of long-run petroleum "futures" is complete without some treatment of current thinking on the subject of how disruptions may unfold. Disruptions are short-run phenomena in the sense that they are emergencies and require

immediate action by the government and other participants in the world oil market. However, they are also long-run phenomena in that they can occur anytime over the next few decades and that preparation for them must be continued for a long time. Indeed, disruptions -- and the adequacy or inadequacy of consuming countries' responses to them -- may prove the most important single factor in explaining the oil price path over this period.

DISRUPTION FORECASTS DEFINED

No one can say with certainty whether another oil supply disruption will occur or when it will happen. Disruption forecasts are a series of generalizations about oil supply disruptions' essential characteristics. These accounts reflect the application of economic theory (and, in some cases, political analysis) to the study of past disruptions. Typically, they seek not only to help decision makers and others to understand the past but also to predict how oil market participants are likely to behave in a future supply disruption. The goal of these predictions is better policy making. Frequently, therefore, "disruption forecasts" include both an "objective" component or <u>prediction</u> of what is likely to happen and an "advocacy" component or <u>prescription</u> of policies to limit disruptions' economic damage. DoD needs to apply the relevant parts of both components in designing its policies for dealing with disruptions.

THREE DISRUPTION FORECASTS

Disruption forecasts have been written from dramatically different perspectives. One, by energy economist Philip Verleger, defines features of the world oil market generally and asserts that they characterize both future disruptions and the disruptions that occurred in 1973 and 1979.[1] A second study, by Erfle, Pound, and Kalt of Harvard's Energy and Environmental Policy

[1] Philip Verleger, <u>Oil Markets in Turmoil</u>, Ballinger, Cambridge, 1982.

Center, focuses primarily on adjustments within the U.S. oil products market in 1979 and employs political analysis as well as economic theory to account for why market participants behaved as they did.[2] Neither of these approaches is explicitly written from the perspective of what economists call macroeconomics. (Macroeconomics involves the study of aggregates within the economy and focuses on issues such as the level of resource utilization, the price level, and the growth of the economy's potential to produce.) A third disruption forecast, by Knut Mork of the University of Arizona and Richard Gilbert of the University of California, explicitly focuses on how disruptions affect the macroeconomy.[3]

The following sections highlight features of these three disruption forecasts as they appear relevant to DoD energy policy.

The Verleger Forecast

Verleger believes that, in future disruptions, market participants will behave the way they did in the 1973 and 1979 disruptions. He pays special attention to price movements in related oil markets and to inventory behavior.

Before considering Verleger's model, readers should understand the terms he uses. "Crude" markets trade petroleum in the same state that it is pumped from the earth; "product" markets trade refineries' output-- fuel oil, diesel, gasoline and other products that final consumers use. The "contract market" refers to long-term arrangements between producers and their customers. The "spot market" refers to short-term transactions between all kinds

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[2] Stephen Erfle, John Pound, Joseph Kalt, The Use of Political Pressure as a Policy Tool During the 1979 Oil Supply Crisis, Kennedy School of Government, April 1981. For convenience, we refer to this work as the "Erfle study" or "Erfle forecast."

[3] "The Economic Cost of Oil Supply Disruptions" by K. A. Mork and "Coping With Oil Supply Disruptions" by K. A. Mork and R. J. Gilbert. Both are contained in Energy Vulnerability, James Plummer, ed., Ballinger, 1982.

of oil owners. Spot markets exist for both crude oil and oil products; both commodities are also traded through contracts.

Verleger focuses on oil price movements that the entire economy experiences. This chapter adopts the same focus. Of course, DoD does demand some petroleum products for which few other customers exist. However, prices of DoD-unique products will move in the same way as other oil product prices since even the unique products reflect the price of crude, transportation, and refining.

Verleger's analysis notes that, at the outset of a disruption, the spot price moves up. (The spot price may not do so immediately because it is not necessarily clear that aggregate production is falling off. Because of the six-week-long tanker "pipe" from the Persian Gulf to Western markets, moreover, actual shortages need not become immediately evident.) When spot prices do increase, producers do not immediately revise contract crude prices upwards. In fact, Verleger provides data that show several months' lag between price hikes for spot crude and those for crude bought on contract. In addition, Verleger demonstrates that dramatic gaps can sometimes develop between the price paid for crude on contract and the price that same crude will fetch on a spot basis. (For example, in March 1979 the contract price of a barrel of Arab Light crude was $13.98; its price on the spot market was $25.74, 84 percent higher.)

Economic theory says that the spot price of oil represents its <u>marginal</u> value. Regardless of the average price of oil traded, in other words, the spot price represents what a purchaser would have to pay for <u>one more barrel</u>. (Conversely, the spot price also represents what an oil owner could get if he were willing to sell it on the spot market instead of using it in another way.) Therefore, economic theory says that profit-maximizing firms

will act as though they paid spot prices for all the oil they own, even though they may have paid substantially less for it.

Verleger's observations about the product market flatly contradict what the economic theory just outlined would lead one to predict. Theory says that refiners should charge more for oil products as the spot crude price rises, regardless of the price they actually pay for crude. Verleger assembles facts that demonstrate that in the 1970s disruptions, many refiners did nothing of the kind. Instead of hiking product prices when spot crude prices went up, most firms increased product prices only months later when contract crude prices increased. Verleger also asserts that this behavior exacerbates the eventual price jump associated with the disruption. When product prices do not change from their predisruption levels, consumption also stays at its predisruption level despite the increased scarcity of oil on the world market. This worsens the situation because people consume more petroleum products than they would at higher prices, thus reducing world inventory. Product prices that do not reflect the rising spot crude price, therefore, set the stage for sharper increases in prices than might otherwise occur.

Verleger also makes some observations about inventory behavior. He argues that people's willingness to hold stocks of oil is sensitive to the disparity between contract prices and spot prices. When spot prices jump above contract prices, people tend to build inventories. This inventory building puts upward pressure on prices because it increases demand at the same time that worldwide supply is being cut back. (The same holds in reverse. When spot prices go below contract prices -- as in the current oil "glut" -- inventory holders sell their stocks and put downward pressure on prices.) Verleger has occasionally characterized this tendency to build inventories as the result of "panic" on spot markets.

Verleger recommends several policies for dealing with disruptions. Some could have direct implications for DoD if implemented, and therefore warrant note here. One recommendation calls for large stockpiles and for procedures that would permit private parties (and <u>not</u> the government) to determine when the SPR should be drawn down, and the rate at which drawdowns should occur.

A second recommendation expressly opposes any price control/allocation scheme for the U.S. economy. These policies would conflict with any DoD proposal for direct allocations from the SPR or from oil companies.

Another recommendation calls for the imposition of an oil import tariff during disruptions and for rebate to the American people of revenue thus raised. Such a policy would reduce the world oil price and increase the price paid by domestic consumers. This proposal could present a new and different challenge for DoD's energy policy since DoD meets about 30 percent of its petroleum requirement through purchases overseas.

Finally, Verleger mentions "promoting calm and orderly spot markets and preventing panic buying and selling." He may not mean this as a serious policy prescription since he provides no details about how government can achieve these goals. In any case, this proposal raises a difficult question for the government once it observes sharp price movement on the spot market. How is it to distinguish behavior reflecting clear judgments based on fast-breaking information from behavior reflecting panic? The proposal also raises the question of how the government should encourage the former and enjoin the latter, even if it could tell the difference. If one assumes that the government will answer both questions to its satisfaction and will proceed to regulate the spot market accordingly, this proposal raises further questions for DoD. Suppose DoD decides that it needs to secure supplies by purchases at or

near spot levels in some future disruption. Will DoD's decision be thwarted by some other government agency that decides not to permit trades at those prices on grounds that they represent panic?

The Erfle Study of 1979: History as a "Forecast"

A somewhat different perspective on how future disruptions may unfold can be discerned in the Erfle study of the 1979 disruption. This study was not written for forecasting purposes but rather to enhance understanding of why U.S. product market participants behaved as they did at that time. However, that study's analysis makes several observations relevant to predicting how future disruptions could affect the U.S. economy and to devising policy responses.

Erfle makes three contributions relevant to DoD energy policy. First, he shows that certain popular images of that disruption reflect flawed understanding of actual events. Second, he offers a political analysis for the economically inexplicable practice of "underpricing" petroleum products (noted earlier in the Verleger forecast). That analysis will help inform DoD judgment about whether such behavior will occur in future disruptions and will be useful in the design of appropriate policies in response. Finally, Erfle makes, in passing, some observations about what policies the U.S. should adopt during disruptions. Even though some of these recommendations conflict with policies DoD might want to implement, DoD should know what he recommends and why.

Erfle focuses on U.S. markets for oil products. He shows why, in theory, the U.S. economy cannot operate efficiently unless spot prices for petroleum products on the U.S. market equal product spot prices on the world market after adjusting for transportation and transactions costs. (This observation is true both for stable markets and for markets experiencing an

oil supply disruption.) He demonstrates that a condition of approximate "product price parity" existed during 1978 when oil markets were stable.[4] However, things were different during the 1979 disruption when "contrary to popular perception, U.S. oil product prices were significantly and consistently lower than world oil prices."

Erfle examines this "underpricing" phenomenon in considerable detail and arrives at several conclusions relevant to DoD energy policy. First, underpricing did not result from governmental price controls. It occurred both in gasoline markets, which were under price and allocation controls, and in heating oil and diesel fuel markets, which were not. Second, not all firms underpriced to the same degree. Major product suppliers, especially large refineries, sold product for prices well under both world spot levels and U.S. spot levels for most of the year. By contrast, independent wholesalers and small refiners sold product for prices much closer to those obtaining on the U.S. spot market. Third, underpricing meant that major product suppliers had to allocate their supplies by some means other than price. Such practices were necessary because consumer demand exceeded available supply at prices below spot market levels. Finally, this excess consumer demand was met on the spot market, for most products. (Gasoline was an exception. In that market, allocation regulations and retail-level price controls prevented price from rationing available gasoline supplies. As a result, some genuine shortages of gasoline occurred during 1979.)

Erfle next attempts to explain underpricing. Why did major suppliers persistently sell product for less than it was worth? He finds the answer in fear of political reprisal. Consumers were upset about higher oil

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[4]U.S. spot product prices were slightly lower than foreign spot product prices. However, the difference was small and remarkably stable through 1978. It grew much larger during the 1979 disruption.

prices, and major oil companies were a highly visible target for their anger. Moreover, these companies feared that consumer anger might result in political pressure for special taxes and additional regulation of the oil industry. As a result, these firms sought to reduce the chances of political reprisal by not passing on, at the wholesale level, price increases that were apparent on world spot markets.

It is hard to say whether, as a result of underpricing, public anger toward the oil companies is less than it would otherwise have been. In fact, Erfle points out some ways in which underpricing caused apparent confirmation of public misconceptions. First, the firms' use of allocation methods other than price led to a public misperception that supply disruptions inevitably lead to product shortages. (As a matter of fact, no "shortage" would exist if prices allocated scarce supplies. Consumers would have to pay higher prices, but could buy all the product they wanted at those prices. For example, auto rental companies experienced no gasoline shortages in 1979. They simply went to the product spot market to meet their requirements.) Second, the disparity between U.S. spot prices and major refineries' lower wholesale prices led to charges that some spot market sellers were "price gouging." (This charge tacitly assumes that major refiners' wholesale prices represent efficient market levels and that spot market sellers somehow succeeded in charging more. This assumption cannot stand up under analysis because spot market prices themselves represent efficient market levels.)

Several of Erfle's points are directly relevant to DoD energy policy. He argues against price controls and allocations. Such a recommendation would conflict with any DoD proposal for preferential treatment via allocations or "directed sales" in a future oil disruption. On the other hand, the recommendation is entirely consistent with a DoD proposal that it

should receive additional budget authority during disruptions to meet its fuel requirements at the higher prices inherent in a spot market source of crude.

More importantly, Erfle argues that, even if the government resists price controls and allocations, future disruptions may well witness a repeat of the underpricing behavior that occurred in 1979. (He argues that the political factors responsible for the 1979 behavior will continue to be present. Consumers will be angry at rising prices and/or "shortages", oil companies will remain highly visible, and Congress will remain sensitive to pressure that it "do something" by imposing new taxes or regulations.) This prospect bears important policy implications for DoD. Two examples of such implications are given below.

In discussions of supply assurance policy, some Defense Fuel Supply Center (DFSC) officials have stated that they prefer policies that permit them to deal with relatively few major oil companies and large refiners rather than with many independent wholesalers and small refiners. To see how the prospect of underpricing in a future disruption could affect DoD, assume that DFSC arranged to meet the bulk of its requirements through major product suppliers. Such relationships might work well in normal markets but might not during disruptions. In fact, if large firms underprice in future disruptions as they did in 1979, DoD faces the prospect of being cut off. After all, large firms that underprice in future disruptions will face greater demand than their supplies will permit them to meet, just as they did in 1979. Accordingly, those firms will have to allocate supplies via means other than price, just as they did in 1979. In such a situation, it is entirely possible that major firms will allocate their scarce product supplies to non-DoD customers. Firms might take this action to avoid the red-tape disadvantages of dealing with DoD. Alternatively, firms might do it because they do not want to offend the

consuming public and judge that cutting off DoD is least likely to encourage a political backlash.

The contract regulations constraining DFSC in purchasing fuels provide a related example of how Erfle's disruption analysis may prove policy-relevant for DoD. Existing law requires that DoD pay product prices commensurate with those paid for substantial quantities of comparable products traded by private buyers and sellers.[5] This requirement effectively limits DoD's ability to make product purchases at spot market prices: while spot price data are readily available, information on the volumes exchanged for these prices is not. This requirement presents no problem in nondisrupted markets: in such periods, DoD is able to meet its requirements in the contract market and adequate supplies are available at prices prevailing there. However, Erfle's analysis suggests that a future disruption may cause major oil companies to underprice what they sell on a contract basis. If so, some customers may have to pay much higher spot market prices to meet their requirements. In other words, underpricing may make the relatively costly spot market DoD's only option for securing adequate supplies. This conclusion bears a message for DoD energy policymakers if they accept Erfle's judgment that underpricing may recur: DoD should seek change in the law and/or its interpretation so that it can make substantial spot market purchases in the event of a future disruption.

Mork and Gilbert: A Macroeconomic Analysis of Disruptions

A third "disruption forecast" can be discerned in a recent paper by Knut Mork of the University of Arizona and Richard Gilbert of the University of California, and in a second paper by Mork alone. For convenience, this

[5]Relevant statutes are the Truth in Negotiations Act (PL 87-653) and the Cost Accounting Standards Amendment to the Defense Production Act (PL 91-379).

study will simply refer to Mork, even though much of what is discussed came from the coauthored paper.[6]

Mork focuses on the macroeconomic consequences of oil supply disruptions. In other words, he is interested in disruptions' effects on unemployment, inflation, and the growth of the economy's potential to produce. DoD policymakers may feel, therefore, that Mork's observations bear limited relevance to DoD energy policy. However, based on his macroeconomic disruption forecast, Mork makes policy recommendations that seek to mitigate disruptions' harmful effects on the economy generally but may have particular implications for DoD. Accordingly, Mork's analysis warrants attention in any defense-oriented survey of forecasts.

Mork distinguishes two kinds of costs imposed by oil supply disruptions. The "supply side" cost arises from the disruption's transfer of purchasing power from Americans to foreign oil producers, thereby decreasing the amount of goods and services available to the U.S. economy. The "demand side" cost arises from the increased inflation and unemployment and decreased investment caused by the disruptions. Mork's analysis indicates that demand side effects are far more serious than supply side effects. He says demand side costs comprise 70 percent to 90 percent of the total costs imposed by a disruption.

Appendix D provides more detail on Mork's analysis. The following discussion focuses on policy implications of this analysis and their relevance to DoD energy policy.

Mork recommends against imposing a disruption tariff. In other words, his disruption forecast leads him to a conclusion opposite that of Verleger, who favors a disruption tariff. More importantly, these experts'

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[6] Mork and Gilbert, op. cit.

opposing recommendations suggest that DoD cannot assume that either policy will necessarily be implemented in a future disruption. Thus, DoD must form energy policies that will work well whether or not a tariff is imposed.

The fact that the government may or may not impose a disruption tariff during a supply emergency raises some important questions for DoD. How would the presence or absence of a disruption tariff affect DoD's ability to assure oil product supplies? What position should DoD take regarding a disruption tariff if the issue surfaces in Administration policy discussions? Can legal research shed any light on how DoD would likely be treated by a disruption tariff if Congress passed such a tariff without special DoD provisions? Are any changes in current oil product procurement practices warranted in light of possible disruption tariffs?

No attempt to answer those questions is made here. However, a brief aside regarding the first question will show why disruption forecasts are not mere academic exercises but are immediately relevant to sound decisions on DoD's supply assurance policies.

Although unable to predict the effect of a disruption tariff (or lack of one) on DoD, some important possibilities can be outlined. Any disruption tariff would make the price of domestic oil products higher than the already-high world prices caused by the disruption. This effect might or might not be good for DoD. For example, the tariff might cause major product suppliers to stop underpricing. If so, prices in the contract market might reach levels that would reduce civilian sector demand sufficiently so that DoD would not have to resort to spot market purchases. In addition, a tariff would cause the world product price to fall, so that DoD might enjoy lower prices overseas than would otherwise obtain. On the other hand, the tariff could bring these good results for DoD only at the price of higher spot and contract prices at home.

Mork's remarks concerning stockpiles' use are also relevant to DoD energy policy. He recommends that stockpiles be drawn down not simply to reduce a disruption-induced price shock but to reduce the unemployment increases that such shocks cause. This observation may be relevant to DoD's calculations regarding whether to oppose SPR drawdown in a future supply disruption. If such a disruption is merely an economic emergency and not a military emergency, some DoD officials might be inclined to "save" SPR oil for the latter kind of crisis. Mork's analysis suggests that such a policy implies putting more Americans out of work. Since DoD does not want to increase unemployment here at home, it should be aware of Mork's analysis.

MODEL ASSESSMENT

The previous sections laid the groundwork necessary for an assessment of disruption forecasting models. However, not all of this study's criteria are equally appropriate for such models. Accordingly, the disruption forecasts are assessed here on the basis of three of the seven criteria; assessment on the basis of the other four is presented in Appendix D. The assessment presented here refers to qualitative models, not formal mathematical ones. Taken together, these observations warrant the conclusion that these models are relevant to DoD energy policy and that DoD energy policymakers should keep abreast of further research developments in this field.

The critical criterion for assessing the forecasts presented in this chapter is: does the model offer insights about disruptions? Each of these models does, but no decision maker can simultaneously agree with everything these models say. Accordingly, model assessment requires consideration of two other criteria: do these models rely on credible assumptions and are these assumptions testable against evidence? Many key assumptions can be so tested, and the results of that testing suggest that DoD should regard some of the

assumptions skeptically. To show why, the following paragraphs evaluate predictions by disruptions forecasters.

Prediction 1: Producers Will Delay Contract Crude Price Increases

Verleger notes that, after spot crude prices went up, oil producers waited for months before increasing their crude contract prices. Historical evidence clearly supports that assertion. He expects similar behavior in future disruptions. However, DoD decision makers should be skeptical of that prediction.

There is reason to doubt that oil producers will sell crude on contract in any future disruption for less than the spot market says it is worth. This doubt holds across a wide range of assumptions regarding producer behavior. Suppose nondisrupted producers perceive their long-run self-interests to include limiting damage to developed economies. If so, these producers should not sell crude at less than spot prices -- they not only earn less themselves, they also risk increased damage to developed economies by doing so. Moreover, this economic damage will be apparent during future disruptions even if it was not recognized in the past. The three "disruption forecasts" reviewed in this study are widely known in the energy analysis community; all three agree that consuming economies suffer less efficiency loss in disruptions if prices do reflect petroleum's increased scarcity at that time. Suppose, on the other hand, that producers do not care about damaging Western economies and seek only to maximize their nations' immediate self-interests. In that case, they should charge the spot price for all their crude, to extract every penny that consuming countries are willing to pay for the crude. In short, producers may well charge high prices whether they want to maximize their welfare or that of consuming countries. DoD decision makers

should, therefore, be skeptical about Verleger's prediction that producers will delay contract crude price increases.

Prediction 2: U.S. Product Prices Will Lag World Product Prices

Verleger says that U.S. crude and product prices go up only after producers increase crude contract prices. Since he anticipates lags in contract crude price increases, he expects lags in product price increases as well. In other words, he expects that U.S. product prices will not move up with product price increases on the world spot market. The previous section shows why crude contract prices might not lag in the next disruption. Accordingly, DoD decision makers should be wary of accepting Prediction 2 on the basis of Verleger's argument.

Erfle also predicts that U.S. product prices will lag world product prices.[7] However, he provides the political explanation cited earlier in this chapter to account for this lag. Despite his convincing political analysis, DoD decision makers should be skeptical of Erfle's political explanation for Prediction 2. Such skepticism is warranted for two sets of reasons. First, Erfle does not explicitly discuss any relationship between producer delays in increasing contract crude prices and refiner delays in increasing product prices. This is a significant omission since such a delay occurred in 1979 and may have been critical to the way firms behaved then. After all, the contract crude price was dramatically lower than the spot crude price in 1979 and gave refiners considerable flexibility in deciding whether or not to delay product price increases. This fact may have made them more inclined than otherwise to respond to perceived political pressure. In addition, a contract

[7]He also makes an unusual distinction -- between U.S. spot prices and "world" spot prices. Most sources do not use such categories since the spot market is a world market.

price lower than the spot price meant that profit-maximizing behavior could be attacked as "profiteering." Thus, in 1979 the fact of low contract crude prices relative to spot crude prices gave refiners the flexibility to underprice and an incentive to do so. Erfle's failure to explicitly recognize this circumstance does not lend credence to his explanation for Prediction 2.

DoD decision makers should be skeptical of Erfle's acceptance of Prediction 2 for a second set of reasons. Most obviously, Prediction 2 implies that large oil companies will choose to lose money in the next disruption even if producers delay contract price increases. Moreover, it implies that these firms will choose to do so even though they know that small refiners and independents have no incentive to lose money as well and, as Erfle proves, did not do so the last time. In addition, Prediction 2 implies that large oil companies will make this choice even though it did not protect them from public hostility in 1979. In fact, as Erfle shows, delays by these firms in increasing product prices contributed to misperceptions causing further erosion of oil companies' public image. Finally, Prediction 2 implies that large oil companies will delay product price increases even though their action is contrary to what influential energy analysts see as the nation's economic interest. (Both Verleger and Erfle argue persuasively that such delays <u>increase</u> the costs that disruptions impose on the U.S. economy. Their view on this point seems to be broadly accepted.) DoD decision makers may judge that such analysts will influence political leaders in any future disruption. (Indeed, analysts thinking along these lines have already convinced important conservative politicians to "let the market work" in any future disruption; President Reagan vetoed Congress's attempt to empower him to reimpose national price and allocation controls.) If so, these leaders may intervene in ways that <u>encourage</u> large oil companies to increase prices. (For

example, a recent RAND study suggested that the government should consider "'reverse jawboning' [via] a declaration that it is in the national interest that everyone sell to the highest bidder."[8]) The prospect of such intervention does not lend credence to Prediction 2.

Prediction 3: Firms Will Increase Their Oil Inventories During Disruptions

This assertion is central to Verleger's analysis. He has accounted for this behavior in different ways, however. Sometimes he ascribes it to "panic;" sometimes he admits the possibility that it may represent "rational responses to the economic situation;" and sometimes he explicitly suspends judgment on the issue.[9] DoD should not be similarly undecided, however. The question of whether inventory builders are acting rationally or panicking bears implications for supply assurance policy. If firms build inventories out of panic and therefore do not sell to DoD, DoD can use this fact to argue for allocation authority. On the other hand, if DoD thinks that firms build inventories for rationally calculated economic advantage, it can get all the oil it needs merely by getting Congressional appropriations to pay spot prices.

Verleger does not provide much description of "panic" behavior except to say that consumers and suppliers "hoard." This term connotes selfish individual behavior that makes society worse off. A common example: in disruptions, consumers frequently top off their gas tanks because they fear shortages. In so doing they create a shortage relative to the situation that

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[8]Hoffman, Seidman, and Hagga, "Legal Constraints on Market Response to Supply Disruptions," RAND Note, June 1982.

[9]For examples of each, see Verleger's work as follows: "When the Oil Spigot Is Suddenly Turned Off," Journal of Policy Analysis and Management, Summer 1982, p. 542; Oil Markets in Turmoil, Ballinger, 1982, pp. 26-27.

would otherwise exist. People who construe such consumer behavior as "panic" might also imagine potential suppliers (e.g., refiners, distributors, and large users like utilities) behaving the same way. Accordingly, DoD decision makers may wish to assess the "panic" explanation for inventory building by comparing it with the "rational" explanation and then deciding which they find more plausible.

One rational explanation for inventory building follows. When firms see spot prices rise above contract prices, they suspect that the contract price is also going to rise. They try to beat this price rise by buying and holding as much crude as they can at the relatively low contract price. In addition, they build inventories by cutting back on deliveries. (DoD decision makers should note that cutting deliveries to DoD does not anger voters and provoke them to put pressure on Congress to punish the oil industry. Accordingly, firms in that industry may choose to build inventories by cutting back on deliveries to DoD. They could do so easily, legally, and promptly, by not responding to the next solicitation and by permitting their existing contracts to expire.)

Unlike "panic" behavior, rational inventory building need not make society worse off. In fact, unless stock building firms are <u>systematically wrong</u> in their predictions about price movement, rational inventory building will make society better off. If their predictions are right, these firms' actions will effectively shift oil from a time when it is abundant relative to demand (and hence relatively cheap) to a time when it is relatively scarce and costly.

This circumstance bears implications for DoD policy. If DoD chooses to argue that firms build inventories from panic, it can also assert that they thereby hurt society as a whole. Therefore, DoD can argue that it helps

society by obtaining some of these firms' inventories through allocations. (This is a difficult argument to make since it presumes that DoD knows more about the oil market than do other market participants. It requires DoD to assert that the other participants' desire for fuel necessarily reflects panic while DoD's desire for fuel does not.) If, on the other hand, DoD judges stockbuilding to be rational, then it has to recognize that society may be hurt when it seizes supplies via allocations. In fact, DoD only helps society in this circumstance if it has superior wisdom and knows that future prices will be lower than inventory holders expect. If that is true, DoD has a weaker argument for seizing private supplies. It should perhaps tighten its belt instead and allow prices to fall.

Prediction 4: A Disruption's Costs in Terms of Inflation, Unemployment, and Reduced Investment Will Greatly Exceed Its Costs in Transferring Purchasing Power Overseas

Knut Mork makes this prediction. It underlies his policy recommendations against a disruption tariff and for speedy SPR drawdown to reduce unemployment. Since these policies may well prove relevant to DoD, a few points are made assessing the Mork argument.

First, certain kinds of empirical evidence support Mork's argument and his theoretical approach. For example, Mork's "classical" approach predicts increases in both inflation and unemployment as a result of supply disruptions. By contrast, the once-dominant Keynesian view associated deflation with recession and inflation with booms. Experience after the 1973 and 1979 disruptions suggests that Mork's argument is better founded on the facts. Another example: Mork predicts a decrease in investment activity as the result of disruptions. Just such a decrease was noted in the aftermath of the 1979 disruption.

Second, Mork does not directly address Verleger's main argument for a disruptions tariff or the underpricing behavior that Verleger and Erfle find central to the cause of disruptions. Mork sees the tariff as a means of preventing supply-side costs (i.e., the transfer of purchasing power overseas). Verleger, on the other hand, sees the tariff as a means of insuring that prices rise to spot levels quickly during a disruption. Mork opposes the tariff because (by driving domestic prices higher than they would otherwise go) a tariff would exacerbate the shift in "relative prices" that accounts for demand-side losses.[10] Thus, Mork does not explicitly recognize the fact that, historically, the relative price shift has been dampened by producers' and refiners' failures to increase prices quickly during disruptions. DoD decision makers should not, therefore, reject Mork's analysis, but they may wish to be cautious in their predictions about whether or not the government will impose a disruption tariff in any future price shock.

CONCLUSION: WHAT DO DISRUPTION FORECASTS TELL DoD?

Disruption forecasts are complicated, and not all forecasters address the same subjects. Nevertheless an attempt is made in Table 5-1 to capture much of this chapter's analysis in a nutshell. Points most crucial to DoD are highlighted in the next few paragraphs.

Disruptions forecasters disagree on many issues, but they all agree that price controls and allocations make economic conditions worse. DoD may therefore wish to hedge against supply assurance policies that presume this form of government intervention.

Disruptions forecasters tend to recommend that society should rely on market mechanisms in any future disruption. DoD should recognize two features

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[10] See Appendix D for a definition of relative prices and an explanation of how relative price shifts cause demand side losses.

TABLE 5-1. DISRUPTION FORECASTS SUMMARY

Forecaster	Predictions	Prescription	DoD Implications
Verleger	* Contract crude price increases occur months after spot crude price increases	* Do not impose price controls and allocations; they make the U.S. worse off	* Allocations to DoD will be hotly opposed
	* Product prices do not rise until contract crude prices rise	* Permit private parties to determine the timing of SPR drawdown	* DoD veto over SPR drawdowns will be hotly opposed
	* Firms build inventories when spot prices exceed contract prices	* Impose an oil import tariff during disruptions	* DoD may face high prices at home and low prices overseas, due to the disruptions tariff
	* Inventory-building may represent "panic" or "rational" behavior	* Build large stocks	
Erfle	* Large U.S. refiners charge less than world spot prices for products	* Do not impose price controls and allocations; they make the U.S. worse off	* Allocations to DoD will be hotly opposed
	* Large U.S. refiners do not allocate by price during disruptions, seeking to minimize voter anger		* Large U.S. refiners may cut DoD off in future disruptions
	* Small refiners and independence charge prices closer to world spot prices for products, so supply can meet demand		* DoD should secure the authority to pay the world spot price
Mork	* Increased inflation and unemployment and decreased investment cost the U.S. economy much more than the transfer of purchasing power to foreign producers	* Do not impose price controls and allocations; they make the U.S. worse off	* Allocations to DoD will be hotly opposed
		* Do not impose an oil import tariff during disruptions	* DoD may face the same prices at home and abroad
		* Draw down SPR to reduce unemployment	* Successful DoD opposition to SPR draw will increase unemployment

of this recommendation. First, it is not a mere reflection of ideology; these forecasters agree on the utility of market mechanisms despite their disagreement on many other issues. Second, advocacy of market mechanisms does not imply a "do-nothing" role for the government. Verleger and Mork argue that government should build a large SPR and recommend that government impose special taxes and quickly rebate revenues. Erfle makes few explicit prescriptions, but his theory is entirely consistent with a large SPR, revenue recycling, and government intervention via "reverse jawboning" as noted before.

These forecasters' observations leave little doubt that a future disruption could pose severe problems for DoD supply assurance. Accordingly, some suggest ways for DoD to respond. An example: Erfle suggests that large refiners may underprice their products and allocate them by some means other than price but that supply can meet demand if small refiners and independents sell products near spot market levels. This description tends to suggest that DoD should get authority to pay spot prices in a future disruption and not be bound to the prices that large refiners charge.

Aside from such suggestions, disruption forecasts help DoD decision makers in three general ways. First, they suggest such fruitful areas for further research as how DoD would be affected by a disruptions tariff, the feasibility of DoD purchases on spot markets, and the utility of buying SPR allocations via futures markets. Second, they inform DoD decision makers about the kinds of challenges they might face in a future disruption. (For example, they show why supply assurance problems could arise from dealing with large oil companies rather than small refiners and independents.) Such predictions may or may not prove accurate. However, DoD can more wisely shape policies to "hedge" if it is aware of all possibilities. Finally, disruption forecasts inform DoD of other perspectives on how this country should prepare

to meet future supply disruptions. This information may or may not change DoD's outlook on its preferred supply assurance policies, but it should better enable DoD to defend its chosen policies more effectively.

APPENDIX A. ASSESSMENT CRITERIA

This appendix provides a detailed description of how the assessment criteria given in Chapter 1 are derived from specific DoD goals stated in Defense Energy Program Policy Memorandum (DEPPM) 83-1.

The format used to introduce these criteria reflects the connection between DoD's proposed actions, on one hand, and this study's forecast assessment on the other. (Here and below, the term "forecast" refers to both the models examined and the particular predictions resulting from them. This study uses the term "forecast" in a very broad sense, subsuming several approaches for informing decisions in the face of an uncertain petroleum future.) Specifically, each "action" cited below is taken verbatim from DEPPM 83-1. The following discussion provides a brief statement of how forecasts may prove relevant to performing these actions and amplifies this with a brief discussion. Logical criteria for assessing forecasts follow from the action and the statement of relevance. Each criterion is stated as a question.

Action: Goals Update

Review and update Department of Defense energy management goals ... contained in the draft Long Range Logistics Plan.

Relevance of Forecasts and Discussion. DoD's Long Range Logistics Plan (LRLP) specifies energy management goals associated with particular (and somewhat dated) forecasts of energy supply and demand over the next several decades. The forecasts survey presented in Chapter 3 helps compare the current LRLP forecasts with others used by government and private industry. If the other forecasts are credible, the survey can help DoD judge the credibility of the LRLP forecast.

Criteria. Is the forecast used elsewhere in government or private industry? Does it rely on credible assumptions?

Action: DoD-SFC Memorandum of Understanding

Develop a memorandum of understanding with the United States Synthetic Fuels Corporation (SFC) that clearly delineates DoD synthetic fuel objectives.

Relevance of Forecasts. DoD and SFC have both common and conflicting interests. Forecasts can help DoD identify where it agrees with SFC on proposed actions and where it does not.

Discussion. At current world prices, synthetic fuels cost much more than petroleum fuels. (Consequently, the private sector does not emphasize synthetic fuels development. This is one reason why Congress established the Synthetic Fuels Corporation.) If world oil prices should go up, however, synthetic fuels would appear more attractive. The SFC, therefore, has a vested interest in forecasts that predict increasing crude prices. DoD, on the other hand, has a vested interest only in accurate price forecasts. Since no one can confidently identify such forecasts before the fact, DoD needs analysis that can help it make informed judgments regarding various plausible oil price paths. Forecasts can form an important part of such analysis if they (1) show what different views of the world imply for future price paths, (2) do so in terms comprehensible to busy decision makers who lack time to be modelers themselves, and (3) specify assumptions that can be evaluated in light of evidence.

Criteria. Does the forecast specify assumptions that can be tested against evidence? Does the forecast inform judgment about future price paths?

Action: Supply Assurance Stockpiles

Evaluate and modify, as necessary, the DoD supply assurance program. Areas to be examined include crude exchanges, procurement practices and patterns, and overseas supply programs.

Relevance of Forecasts. Forecasts can help DoD evaluate the advisability of establishing its own petroleum reserve. If DoD seeks to build such a reserve, forecasts can help establish arguments for doing so.

Discussion. Building stockpiles imposes costs. Stocks are worth building only if expected benefits exceed these costs. Some forecasting models considered in the LMI survey have been used elsewhere in the government to estimate these benefits and to define the value of an additional barrel of stockpiled oil in excess of its market price. DoD can make better choices about building stockpiles and can argue more persuasively for these choices by knowing how estimates of this value flow from forecasting models.

Criterion. Does the forecast help DoD estimate the value of a petroleum stockpile in excess of its cost?

Action: Oil Shale Program

Work with the Department of Energy and the SFC to design a program to develop Naval Oil Shale Reserve No. 1.

Relevance of Forecasts. Oil shale may prove to be an important source of energy in the future as DoD transitions from current fuels and technologies to alternative energy forms. Any program to develop this resource will need to specify the amount of shale oil fuel production capacity it seeks. Ideally, forecasting models would help DoD make this specification.

Discussion. Some forecasting models have been used to investigate the consequences of alternative assumed levels of unconventional fuel supplies, such as oil shale. DoD's oil shale program will be more credible if it reflects awareness of this analysis.

Criterion. Does the forecast make predictions about the transition from current energy sources to future forms?

Action: Energy Emergency Preparations

Complete procedures to minimize disruptions in DoD and the Defense industrial base during an energy emergency ....

Relevance of Forecasts. DoD may choose any of a number of alternative procedures to deal with supply disruptions. Whatever its choices, DoD must be prepared to defend its proposals and it can do so most effectively if it is aware of disruption forecasts.

Discussion. No one can say with certainty when supply disruptions will occur. Nevertheless, respected energy experts have predicted how market participants will behave when another supply disruption hits. DoD can better design its policy proposals if it is aware of these existing forecasts and the evidence adduced in making them.

Criterion. Does the forecast offer insights or predictions about how supply disruptions will unfold?

APPENDIX B. SUPPORTING DETAIL ON LONG-RUN ECONOMIC FORECASTING MODELS

This appendix provides supporting detail about the EMF intertemporal optimization models mentioned briefly in Chapter 3 but not analyzed. It also compares representative examples of structurally distinct forecasting models.

INTERTEMPORAL OPTIMIZATION MODELS

Figure B-1 displays price paths forecast by three intertemporal optimization models under the EMF "reference case." (For expository simplicity, these forecasts were not introduced in the text.)

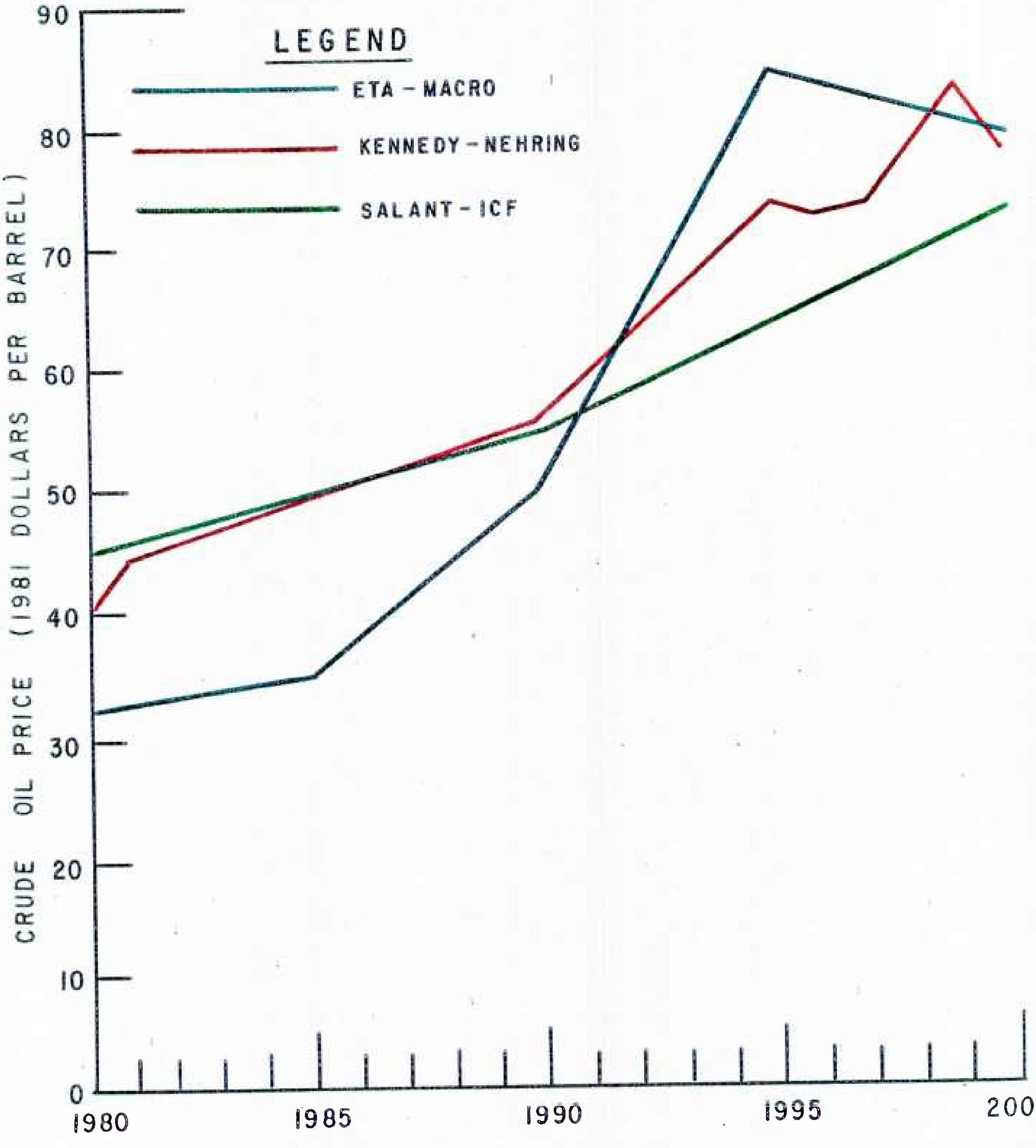
The Salant-ICF forecast shown in Figure B-1 was generated by a computerized model structurally similar to the Salant model described in Chapter 3. This forecast apparently corresponds to Price Path D (in Figure 3-5) before the "competitive fringe" stops producing oil. The other forecasts follow from EMF reference case runs of other intertemporal optimization models.

Figure B-1 bears out the text's generalizations about forecasting models that even though some sectors are assumed to have perfect foresight in intertemporal optimization models, these models do not necessarily predict smooth price movement over time. Despite their structural similarities, intertemporal optimization models support sharply differing price forecasts. Thus, intertemporal optimization models, like recursive simulation models, do not represent a consensus regarding future prices. This circumstance limits the utility of both approaches to DoD decision makers who seek to reduce uncertainty about future events.

THREE QUANTITATIVE MODELS COMPARED

Chapter 3 provides an overview of model structure, introduces the major distinctions analysts use in categorizing forecasting models, and makes some

FIGURE B-1 EMF WORLD OIL PRICE PROJECTIONS "REFERENCE CASE"/INTERTEMPORAL OPTIMIZATION MODELS



SOURCE: ENERGY MODELING FORUM, WORLD OIL SUMMARY REPORT, FEBRUARY 1982

general observations about the utility of these models to DoD. Most important, Chapter 3 notes that these models do not meet one of the key criteria for forecasting models. (In other words, these models do not (1) require decision makers to form some broad judgments about the future and (2) inform decision makers about what these judgments imply. Instead, as stated in Chapter 3, these models require decision makers to become minutely familiar with details before drawing any firm conclusions about why forecasts differ.) Because of this characteristic, study of these models will probably not give DoD decision makers many insights relevant to policy.

Since these models do not meet the key criterion just mentioned, their ability to meet the other six evaluation criteria was not evaluated. Instead, Table B-1 and the accompanying text provide detail to support the generalizations in Chapter 3 about forecasting models. The following discussion, which provides a fairly detailed description of how three forecasting models work, illustrates the point that extremely detailed knowledge of model structure is needed to explain price path forecasts.

Models in Table B-1 illustrate the categories mentioned in Chapter 3. Both DRI's World Oil Model and the Department of Energy's WOIL model are recursive simulation models. In them, sectors behave on the basis of past and current information but not on the basis of foresight about the future. Salant's intertemporal optimization model, on the other hand, assumes that producers enjoy perfect foresight about future demand. In addition, the competitive fringe knows what price path the dominant firm will set. Similarly, the dominant firm knows what sales path the fringe will follow.

The WOIL model is an example of the systems dynamics approach. Although it too is a recursive simulation model, many of its variables become "endogenized." In other words, after the modeler specifies initial variable values,

TABLE B-1. QUANTITATIVE MODELS COMPARED

	DRI	Salant	WOIL
GENERAL			
Source	Commercial Forecasting Service	Academic Economist	Department of Energy
Type	Recursive Simulation	Intertemporal Optimization	Systems Dynamics/ Recursive Simulation
Foresight	None	Perfect (by producers)	None
Parameter Specification	Econometric	User	Modeler ("benched" to history)
SUPPLY SIDE			
OPEC			
Production Capacity	Exogenous	Exogenous	Capacity Reaction Function
Price Determination	Market Clearing Criterion	Optimization	Price Reaction Function
Quantity Determination	Market Clearing Criterion	Optimization	OPEC as Residual Supplier
Solution Technique	Iterative	Iterative	Recursive
Non-OPEC Suppliers			
Structure	Exogenous	Supply Curves	Production Capacity Submodel (U.S.) Supply Curves (other)
Supply Decisions	Exogenous	Optimization	Demand/Maximum Capacity Utilization
Backstop Technology	No	No	Yes
DEMAND SIDE			
Oil Stocks	Yes	No	No
Long Run Crude Price Elasticity	-0.48 (12 Year)	Exogenous	-0.35 (5 Year)
Income Elasticity	1.0	1.0	1.0
GNP Feedback Effects	Yes	No	Yes
Fuels Modeled	Oil (competing fuels in linked DRI models)	Oil (competing fuels in EMF version)	Oil and competing fuels

feedback loops within the model serve to update these values as the model is run.

These three models differ in how their parameter values are specified. The DRI model relies on statistical analysis of history to estimate these values. The computerized Salant model gives considerable rein to model users to estimate these values themselves. The WOIL model is run with parameter values "benched" to history, and outcomes are compared with actual outcomes to ascertain whether those values generated a good "fit." (This procedure, however, can lead to unwarranted confirmation of the model. The model involves many parameter values. Consequently it is possible to specify many of them improperly and for their joint interaction to lead nevertheless to results spuriously similar to historical outcomes.)

Modeling OPEC

The three models each embody a different system of modeling and "solving for" the behavior of the Organization of Petroleum Exporting Countries (OPEC).

Production capacity is exogenous in the DRI and Salant models. (Here is an example of a qualitative, i.e., judgmental, input to a quantitative model.) WOIL, on the other hand, uses a "capacity reaction function." In other words, it makes production capacity in one period a function of price and demand changes in previous periods. As demand increases and prices move up, the WOIL model makes investments to expand production capacity. (Thus, production capacity provides an example of the endogenized variables that characterize "systems dynamics" models such as WOIL.)

The models require different solution procedures to predict OPEC behavior. The Salant model regards OPEC as the "dominant firm." In that model, OPEC knows what the sales behavior of the competitive fringe will be for any OPEC-chosen price path. It chooses a profit-maximizing price path,

therefore, and supports this path through its production decisions. Similarly, the small producers constituting the "competitive fringe" know what OPEC's price path will be and choose a sales path to maximize <u>their</u> profits. The model iterates under these assumptions until it reaches a set of solutions that neither OPEC nor the fringe would have an incentive to change.

In the DRI world oil model, neither supply nor demand sectors know what the price path looks like before the fact. The model user specifies a price path, however. The model is used to determine whether this path is feasible. In other words, will supply equal demand at those prices? If supply doesn't equal demand, the model user must either change price, or change his exogenously specified assumptions about non-OPEC supply. (Here is another example of judgmental input to a quantitative model.) After these adjustments, the user runs the model again. (Thus, the DRI model relies on an <u>iterative</u> solution procedure even though it is, like WOIL, a <u>recursive simulation</u> model.)

In the WOIL model, price is not changed in a given period if supply does not equal demand in that period. Instead, WOIL assumes that OPEC supplies the difference between non-OPEC production and world demand in a given period. When OPEC production has to increase to do this, however, the price will increase in the next time period. (The amount of increase is specified by the model's "price reaction function.")[1] Hence, WOIL employs a recursive solution technique.

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[1] Like a supply curve, a price reaction function shows how price changes in response to a change in quantity demanded. However, a price reaction function represents oligopolistic suppliers' behavior and thus technically differs from a supply curve.

Modeling Non-OPEC Suppliers

Supply Structure. DRI and WOIL model U.S. production differently from other non-OPEC production. Each distinguishes the output of existing reserves from that of newly added reserves. Production from existing reserves declines geometrically over time; price affects the amount of production from new reserves. (In WOIL, for example, higher prices result in additional investment in oil rigs for increased additions to reserves.)

For non-U.S., non-OPEC production, WOIL defines an aggregate supply curve from an initial price-quantity point and an assumed elasticity of supply. DRI, by contrast, specifies non-U.S., non-OPEC production exogenously. Salant defines a supply curve for both categories of non-OPEC producers.

The three models treat supply decisions differently. Salant solves for these decisions through the iterative optimization routines described in Chapter 3. DRI's World Oil Model defines these decisions exogenously for non-U.S. regions; in DRI's supporting model, U.S. production is a function of production/reserve ratios, prices, and current reserve totals. Supplies from non-U.S. regions in WOIL are a function of the supply curve described above, and the world oil price in a given period. In the U.S., WOIL determines production based upon production capacity, the demand for oil in the region, and a maximum capacity utilization rate. WOIL also considers the impact of a backstop technology; the others do not.

Modeling World Demand. The models display some important similarities in depicting oil demand. For example, all three recognize the importance of overall economic growth by assuming an income elasticity of demand equal to 1.0. (In other words, each predicts a 1 percent demand increase for every 1 percent increase in economic output.) In addition, versions of all three

models explicitly incorporate the price of other fuels in calculating the demand for oil. (This effect is critical; if natural gas prices fall, for example, oil demand will fall as users substitute gas for oil.)

The models also differ in depicting oil demand. DRI and WOIL explicitly incorporate GNP feedback effects. (In other words, they attempt to capture the effects that oil price changes have on overall economic activity, which in turn feed back onto oil demand. For example, rising oil prices depress the economy and reduce oil demand, thus dampening somewhat the oil price increase.) In contrast, the Salant model does not model GNP feedback.

DRI distinguishes between changes in oil stocks on one hand and oil consumption, on the other; WOIL and Salant do not. DRI makes this distinction to capture the seasonal element in petroleum demand. (Refiners build heating oil stocks before winter and gasoline stocks before the summer peak driving season.) However, none of these models represents stock demand as a function of the contract price/spot price disparities critical to other analyses.[2] Thus, DRI's treatment misses one of the critical determinants of stock building behavior. This omission means that DRI's stock analysis does not enhance it significantly relative to WOIL and Salant.

A final set of critical differences between the three models involves their mechanisms for handling the responsiveness of demand to price changes. DRI and WOIL assert that the quantity demanded changes little in response to price changes immediately after they occur but responds more over time. Thus, these two models recognize that people change their consumption patterns slowly after a sharp price rise. When oil prices increase sharply, people continue to use considerable oil because they do not immediately

[2] Chapter 5 presents a discussion of crude prices, spot prices, and stock-building demand.

replace "gas-guzzling" cars or get rid of existing housing in favor of energy-efficient designs. Over time, however, people do change their oil-using capital stock. In fact, the quantity of oil society demands at a high price will drop dramatically, but it will do so slowly. The Salant model does not embody such recognition, perhaps for reasons of computational feasibility.

APPENDIX C. SUPPLEMENTAL INFORMATION ON DECISION ANALYSIS APPROACHES

This appendix describes and evaluates the Saaty model for oil price forecasting. It then provides additional detail about the concept of social surplus that underlies the Teisberg model described in Chapter 4.

THE SAATY MODEL

Thomas L. Saaty has developed a procedure for decision analysis that he terms the Analytic Hierarchy Process (AHP) and has applied this technique to the problem of forecasting oil prices.[1] Because of the model's complexity, the following discussion describes a simplified version of the technique to illustrate the principles involved.

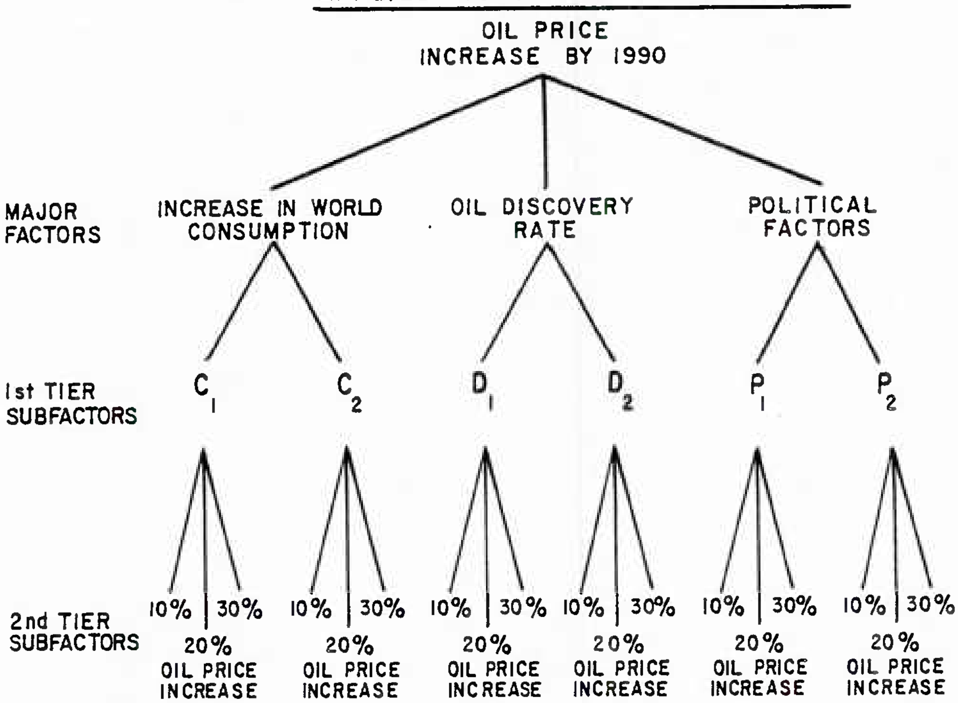
An Overview of AHP

Using AHP requires several steps. The first step requires the policymaker to develop a hierarchy to structure the decision problem. To do this, the policymaker must identify the major factors relevant to the decision. (In the case of oil price forecasting, AHP requires the policymaker to specify the factors judged most important in influencing future oil prices.) In addition, AHP requires definitions of "subfactors," i.e., elements most critical to each of the major factors specified. In principal, this process of structuring the problem could involve several more tiers in a hierarchy. The decision maker could define a second tier of subfactors composed of elements that affect each subfactor in the first tier and so on.

[1] T. L. Saaty and A. Gholamnezhad, "Oil Prices: 1985 and 1990," in T. L. Saaty and L. G. Vargas, The Logic of Priorities, Klower-Nijhoff Publishing, 1979.

In the case of AHP applied to oil price forecasting, Saaty requires users to specify factors and two tiers of subfactors. At the second subfactor tier, he requires users to specify levels of oil price increases that they can judgmentally associate with each subfactor and factor affecting oil prices. Figure C-1 illustrates a simplified version of Saaty's hierarchy for oil price forecasts.

FIGURE C-1 EXAMPLE OF AN AHP HIERARCHY APPLIED TO OIL PRICE FORECASTING



KEY:

C_1, C_2 SUBFACTORS AFFECTING INCREASE IN WORLD CONSUMPTION

D_1, D_2 SUBFACTORS AFFECTING THE OIL DISCOVERY RATE

P_1 SUBFACTOR: DEGREE OF INSTABILITY IN PERSIAN GULF

P_2 SUBFACTOR: INTENSITY OF ARAB-ISRAELI CONFLICT

The second step in AHP involves assigning weights to each of the factors and subfactors. Saaty specifies a selection of weights from a scale of 1 through 9 on the basis of pairwise comparisons. Table C-1 defines the

TABLE C-1. SAATY'S WEIGHTING SCALE[a]

Importance[b]	Definition	Weight[c]
Equal:	Two factors make equal contributions	1
Weak:	Experience and judgment slightly favor one factor over another	3
Strong:	Experience and judgment strongly favor one factor over another	5
Demonstrated:	The dominance of one factor is demonstrated in practice	7
Absolute:	The evidence favoring one factor is "of the highest possible order of affirmation"	9

[a]The definitions stated here paraphrase those Saaty provides in "A Sealing Method for Priorities in Hierarchical Structures," Journal of Mathematical Psychology, Vol. 15, 1977, p. 246.

[b]How important is one factor relative to the other factor, in shaping a particular outcome?

[c]Appropriate "weight" to be assigned to the one factor.

weights on Saaty's scale; an example will illustrate how these weights are used.

> Example. Suppose a policymaker decides that future oil prices are affected by three major factors: the increases in world oil consumption, the oil discovery rate, and political factors. Pairwise comparison means policymakers must ask themselves how important consumption increases are compared to political factors, on a scale of 1 to 9. In other words, they must judgmentally "weight" consumption increases on a scale that says political factors have a weight of 1. If they think that consumption increases are slightly more important than political factors, for example, they give consumption increases a 3. They must also compare consumption increases with oil discovery rates, oil discovery rates with political factors, and so on.

AHP's subsequent steps involve mathematical manipulation of the weights so derived. AHP users must organize the weights derived from pairwise comparisons of major factors into an array of numbers. Since there are three factors, this array will be a "square matrix," three deep and three wide, as shown in Figure C-2.

Saaty's convention is to compare items in the matrix with "row" always preceding "column." Figure C-2 shows what this convention implies for the consumption increases vs. political factors comparison just mentioned: a 3 appears in its upper right hand corner. (For "consistency" as Saaty uses the term, the reciprocal [1/3] appears in the lower left hand cell, which shows the importance of -- note the reversed order -- political factors compared to consumption increases.)

FIGURE C-2 MATRIX OF MAJOR FACTOR WEIGHTS

	P	D	C
P	1	1/5	3
D	5	1	2
C	1/3	1/2	1

KEY

P = POLITICAL FACTORS
C = INCREASE IN WORLD OIL CONSUMPTION
D = OIL DISCOVERY RATE

Once major factor weights are organized into a square matrix, AHP users must mathematically determine the unique solution of that matrix. This solution will be an ordered series of numbers -- an "eigenvector."

The ensuing steps for AHP users resemble those performed for major factors. Users must examine the next tier of the hierarchy and assign weights via pairwise comparisons of subfactors found at that tier. Then users must arrange these weights into square matrices. In addition, they must produce and solve a subfactor matrix corresponding to each major factor. An example will illustrate the procedure.

> Example. Suppose that the policymaker decides that two subfactors correspond to each of the major factors defined above. As Figure C-1 shows, for example, he might decide that the political factors are critically affected by two subfactors, the degree of instability in the Persian Gulf and the intensity of the Arab-Israeli conflict. (For simplicity in exposition, Figure C-1 labels subfactors corresponding to other major factors with symbols only. It denotes subfactors corresponding to the "Increase in World Consumption" by C_1 and C_2 and subfactors corresponding to the "Oil Discovery Rate" by D_1 and D_2.) Given this breakdown of subfactors, the user must make pairwise comparisons among the six first tier subfactors so defined, and arrange the resulting weights into a matrix. At the end of this process, therefore, the user will have three matrices, each of which corresponds to one of the three major factors. Each of these matrices will be six by six in size, reflecting the weights derived from comparing each of six subfactors to itself (for a weight of 1, by definition) and to the five other subfactors. Figure C-3 illustrates such a matrix.

Once AHP users have defined matrices of subfactors, they must calculate the unique solution vectors corresponding to each of the three subfactor matrices. Next, they must array these solution vectors into another matrix.

In applying AHP to oil price forecasting, Saaty applies the methodology described so far to a third hierarchical level. (Figure C-1 labels this level "Second Tier Subfactors.") He requires policymakers to make pairwise comparisons of a number of possible sizes of oil price increases and assign weights accordingly. For simplicity in exposition, Figure C-1 depicts the second subfactor tier that would be observed if Saaty required the user to weight only the prospects of a 10 percent, 20 percent, and 30 percent oil

FIGURE C-3 SQUARE MATRIX OF "WEIGHTS" REFLECTING SUBJECTIVE JUDGMENTS OF SUBFACTORS' IMPORTANCE TO MAJOR POLITICAL FACTORS

SUBFACTORS	C_1	C_2	D_1	D_2	P_1	P_2
C_1	1	3	1/9	6	9	1/2
C_2	1/3	1	2	3	1/5	7
D_1	9	1/2	1	4	8	2
D_2	1/6	1/3	1/4	1	7	8
P_1	1/9	5	1/8	1/7	1	1/8
P_2	2	1/7	1/2	1/8	8	1

KEY: C_1 C_2 SUBFACTORS AFFECTING INCREASE IN WORLD CONSUMPTION
D_1 D_2 SUBFACTORS AFFECTING THE OIL DISCOVERY RATE
P_1 SUBFACTOR: DEGREE OF INSTABILITY IN PERSIAN GULF
P_2 SUBFACTOR: INTENSITY OF ARAB-ISRAELI CONFLICT

price increase. (Saaty wants the user to judge the relative weights of a 10 percent oil price increase compared with a 20 percent oil price increase as these "second tier" subfactors pertain to the "first tier" subfactor of, for example, the degree of Persian Gulf instability.) Further comment on this step is warranted and is provided in the assessment of this model.

Once weights are assigned to second tier subfactors, mathematical manipulations follow the familiar pattern. Users arrange weights in matrix format with one matrix per first tier subfactor, calculate the unique solution of each matrix, and arrange these unique solution vectors into yet another matrix. By following these steps, users of Saaty's AHP find themselves with a vector and two matrices. The vector represents the unique solution of the major factors matrix; the two matrices incorporate the unique solutions of the matrices for the first- and second-tier subfactors, respectively.

Next, users must "matrix multiply" the vector by one matrix by the other matrix. The result will be a series of what Saaty terms "likelihood weights."

Saaty uses each likelihood weight as a probability that a price increase of a specific size will occur. The methodology described above would lead Saaty model users to three likelihood weights, one corresponding to an oil price increase of 10 percent, one to 20 percent, and one to 30 percent. By multiplying each likelihood weight by its corresponding percentage and summing the products, therefore, users can obtain an estimate of the expected percentage increase in oil prices.

Assessment of the Saaty Model

In the past, LMI has recommended use of Saaty's AHP. However, this study does not endorse Saaty's application of AHP to oil price forecasting. To show why, this application is tested against this study's seven model assessment criteria. To underscore this assessment's narrow focus, the following discussion calls this application "AHPF" (Analytic Hierarchy Process for Forecasting).

The AHPF can be quickly assessed in light of four of the criteria, but the other three require some discussion. For convenience, the key words of each criterion are underscored and each criterion that is discussed in detail is introduced with an abbreviated restatement in question form.

Available evidence suggests that AHPF is not used elsewhere for oil price forecasting. AHPF does not help users estimate stockpiles' value, nor does it offer any insights about disruptions or about the transition to backstop technologies.

Credible and Evidence-Testable Assumptions? The structure of the AHPF model imposes one type of assumption and users provide another type. By

definition users will presumably judge the assumptions they provide as credible.

The AHPF structural assumptions cannot be tested against evidence. Judgment of their credibility is also difficult since they cannot be submitted to objective tests. The Saaty model does not, however, provide a clear, explicit, and convincing rationale for some of these assumptions. Accordingly, this study recommends that DoD regard them skeptically. Two exemplary assumptions are discussed in the following paragraphs to substantiate this recommendation.

Consider Saaty's system of weights and his assumptions regarding consistency. If a user gives one factor a 3 when comparing it to a second factor, the weight "3" does not mean that the first factor is three times as important as the second. However, Saaty requires the reciprocal, 1/3, to be assigned when comparing the second to the first. In other words, Saaty relates weights multiplicatively for some purposes but not for others. This apparent inconsistency exists at the heart of Saaty's assumptions about consistency. For this reason, many users will not find those assumptions intuitively compelling.

A second structural assumption inheres to Saaty's placement of oil price increases at the top and the bottom of his hierarchy. On one hand, Saaty wants to use AHPF to estimate oil price increases. Therefore, the overall estimate is at the top of the hierarchy. On the other hand, Saaty needs to develop "likelihood weights" to associate with price increases of different specified sizes (10 percent, 20 percent, etc.). Therefore, he makes such price increase sizes the lowest tier of his hierarachy. Here again, users have to accept this structural assumption or forego use of AHPF, even though the rationale for this assumption is not intuitively obvious.

Inform Judgments About Price Paths? Saaty would argue that AHPF can inform judgment. However, it would not make such judgments easier; users would have to work very hard to get results, and it is not clear that the results would justify their labor. Each of these observations is discussed here.

AHPF users would have to work very hard before the model produced any insights about future price paths. Unless they accept the particular hierarchy Saaty chose, users would have to devise their own. They would have to decide how many tiers to place in this structure and what factors to include in each tier. They would also have to weight each factor via pairwise comparison and do so for a matrix corresponding to each tier immediately higher in the hierarchy.

When, after all the work described above, AHPF finally produced a forecast, users might reasonably doubt that they possess sharper insights about likely future oil prices. Considering the complexity inherent in AHPF procedures, users might want to perform sensitivity analyses to determine which assumptions drive the results. With this additional effort, they may learn more about AHPF and how its structural assumptions affect results. If their knowledge makes them more comfortable with using AHPF, they may even make more confident projections about future world oil prices. Using the Saaty approach to forecast oil prices is so time-consuming, however, that users may reasonably judge that the insights provided by AHPF are not worth the effort expended in obtaining them.

TEISBERG MODEL BACKGROUND: SOCIAL SURPLUS

The Teisberg model relies on the economist's concept of social surplus in computing the costs and benefits associated with stockpile acquisitions and drawdowns. This concept relies in turn on the ideas that a demand curve

represents the price society would be willing to pay for each additional unit of a commodity and that a supply curve represents the real resource cost of producing an additional unit. Figure C-4 depicts these notions graphically.

FIGURE C-4. SOCIAL SURPLUS

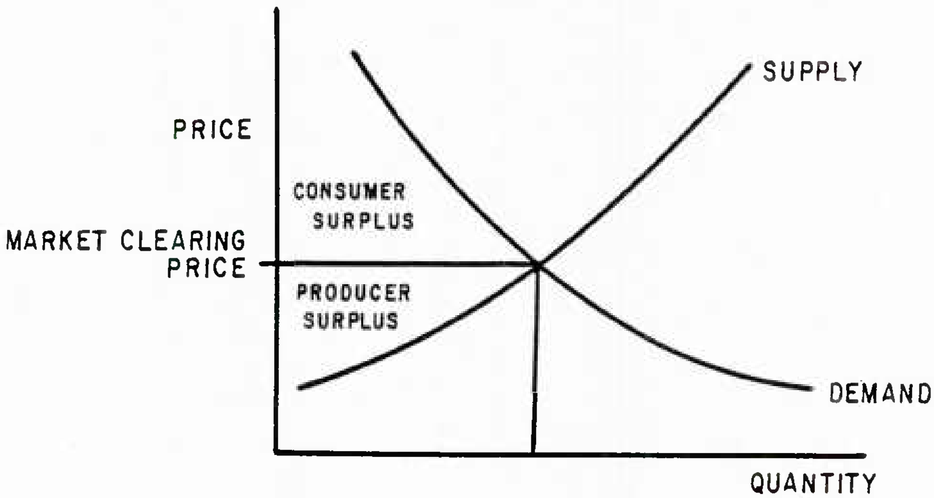
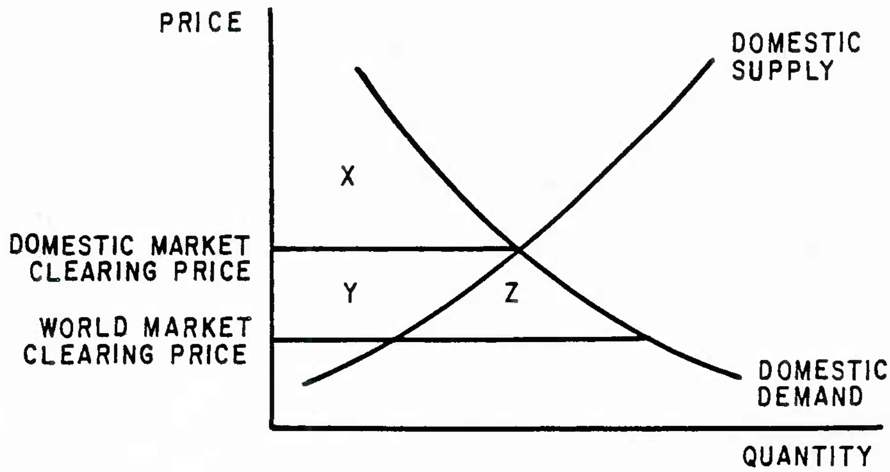


Figure C-4 divides social surplus into two parts. Consumers' surplus equals the difference between what consumers would be willing to pay for a commodity and the price they have to pay. Producers' surplus equals the difference between what producers have to pay to supply a commodity and the market clearing price they charge. (For economists, the "market clearing price" is the one at which supply equals demand.)

The price of oil on the world market is considerably lower than the price at which domestic suppliers would be able to meet domestic demand. (This is the reason why the U.S. imports some 5 million barrels every day.) As a result, this country enjoys greater prosperity than its economy would provide without oil imports. Figure C-5 shows this graphically, in terms of social surplus. Without imports, domestic consumers' surplus would equal area X only; with imports, it equals a much larger amount, X + Y + Z.

FIGURE C-5. IMPORTS INCREASE CONSUMERS' SURPLUS



The Teisberg model estimates the consequences of oil price increases caused by supply disruptions and/or oil acquisition for filling the SPR. LMI does not anticipate price increases in the short run to be so large as to end imports altogether. Accordingly, a disruption's consequences for U.S. consumers' surplus can be depicted with the illustration given in Figure C-6.

FIGURE C-6. SUPPLY DISRUPTIONS REDUCE CONSUMERS' SURPLUS

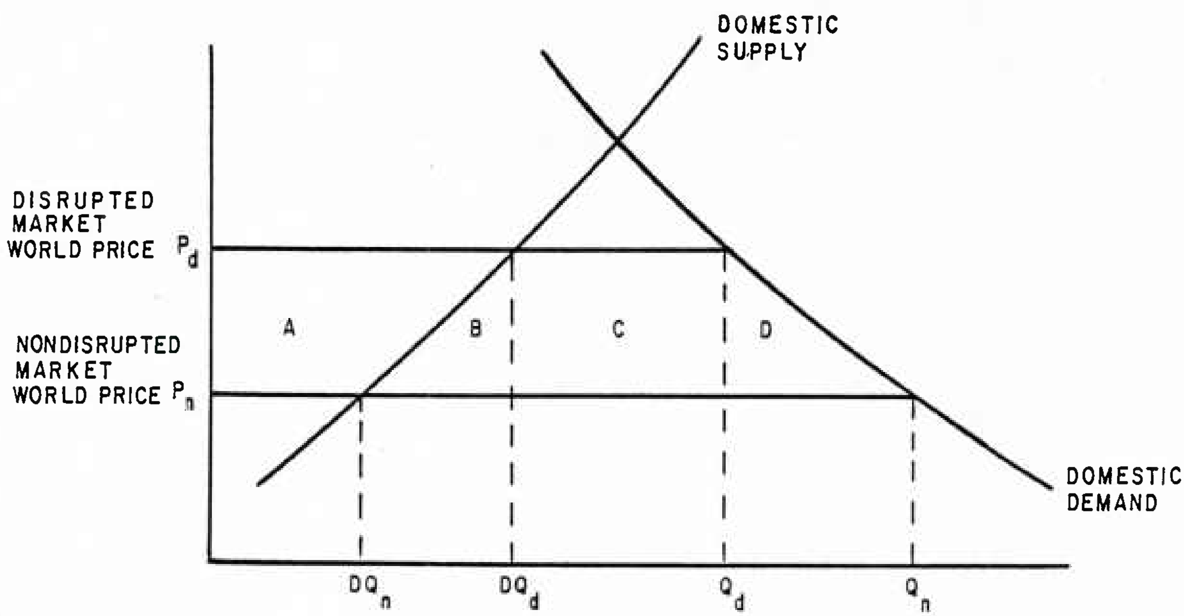


Figure C-6 displays the impact of a disruption in world oil supply that increases world prices from their nondisrupted level, P_n, to the disrupted price level, P_d. This increase reduces consumers' surplus by an amount equal to areas A+B+C+D. However, Area A does not represent a loss of national wealth but simply a transfer from domestic consumers to domestic producers. Accordingly, the Teisberg model does not include Area A in computing the social surplus losses associated with a disruption.

A closing caution: the practice just described may mean that the Teisberg model underestimates the costs of disruptions to the U.S. economy. Even though Area A is a wealth transfer rather than a wealth loss, such transfers are not politically costless. When price jumps enrich oilmen at the expense of the rest of the country, for example, sitting politicians risk punishment unless they "do something" about it. "Doing something" frequently implies actions (e.g., price controls) that make the national economy less efficient and reduce national wealth. It may be argued that the Teisberg model underestimates the cost of price increases since it does not count this component in computing social surplus losses. It counts costs only from Areas B (the cost of increasing domestic production from DQ_n to DQ_d), C (the wealth transfer to foreign producers), and D (the "deadweight loss" consumers suffer since they cannot consume quantity $Q_n - Q_d$ as they otherwise would).

APPENDIX D. SUPPORTING DETAIL ON DISRUPTION FORECASTS

This appendix provides supporting detail about Knut Mork's analysis discussed in Chapter 5. It also discusses disruption forecasts in light of their use elsewhere, ability to estimate stockpile values, and ability to inform judgment on future price paths, the assessment criteria not applied for model assessment in the text.

KNUT MORK'S ANALYSIS: THE IMPORTANCE OF RELATIVE PRICES, AND THE DEMAND-SIDE COSTS OF OIL SUPPLY DISRUPTIONS

The following discussion provides some additional background information on Mork's analysis of disruptions' macroeconomic effects. Although Mork and others did build a formal mathematical model to estimate the magnitude of various macroeconomic costs, this appendix does not discuss that model. Instead, the following discussion provides a layman's overview of the thinking behind Mork's policy recommendations.

Mork distinguishes two kinds of costs imposed by oil supply disruptions. First, he considers the costs of disruptions in terms of the aggregate supply of goods and services in an economy. The principal "supply side" effect is that higher world oil prices mean a decrease in the supply of goods and services available to the U.S. economy. When imported oil increases in price from, say, $12 per barrel to $36 per barrel, $24 worth of command over U.S. goods and services moves from Americans to foreign oil producers. Eventually, therefore, $24 of U.S. goods and services will be exported and not available on the U.S. market.

Mork next considers "demand side" effects: increased inflation and unemployment and decreased investment. A brief review will show how

each of these effects flows from the abrupt shift in relative prices caused by disruptions.[1]

Initially, the high price of oil relative to predisruption levels and to other prices in the economy leads to higher prices for all forms of energy. Higher energy prices then cause higher prices for all other goods and services produced in the U.S. economy. (This increase in prices of other goods and services does not occur only because energy is an input to so many of those goods and services. It also occurs because of the way participants in U.S. markets respond to the changed relative price of oil. They do not respond by cutting the prices charged for other goods and services even though economic theory indicates that such adjustments would be required to avoid an increase in the overall price level. Consequently, a disruption can cause an increase in the overall price level.) Some evidence suggests that over the longer run, higher energy prices cause a decrease in the rate of productivity growth. If, in fact, this decrease occurs, a less-productive economy means fewer goods to buy with available dollars and therefore inflated prices for those goods.

Disruption-induced changes in relative prices also increase unemployment. According to Mork, the demand for labor falls when energy prices increase. Accordingly, real wages would have to go down for labor supply to match labor demand. However, nobody likes to take a lower paycheck, so wages are "sticky downward." The market's demand for labor shrinks relative to predisruption levels, and unemployment rates rise. (To the extent that wages are indexed

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[1]Relative prices refer to the amount of one good one must forgo to consume one unit of another good; it can be expressed as a ratio of the prices of each good in dollars. To see what an abrupt shift in relative prices means to Mork's argument, consider a world in which all goods and services are produced with two inputs: "energy" and "all other." When energy prices rise sharply, demand for all other inputs falls. For producers of all other inputs to remain fully employed, therefore, the price charged for those inputs must fall, as well, relative to their predisruption levels.

to increase with inflation, both inflation and unemployment are higher than they would otherwise be.)

Mork's analysis so far indicates that changed relative prices resulting from oil supply disruptions cause both a recession (i.e., a decrease in goods and services produced by the U.S. economy and an increase in unemployment) and inflation. The problem is even greater, however. In addition, Mork expects the abrupt change in relative prices to lead to substantial decreases in savings and, consequently, decreases in the amount of resources available for investment.[2] (Historically, the U.S. witnessed just such a sharp decrease in investment following the 1979 disruption.) Thus, in Mork's view, oil supply disruptions mean that "the productive capacity of the economy is not maintained, and the recession results in a substantial loss."

SUPPORTING DETAIL ON THE ASSESSMENT OF DISRUPTION FORECASTS

The assessment in Chapter 5 stated that four of the seven assessment criteria were not primarily applicable to evaluating disruption forecasts. DoD will have a fuller understanding of these models, however, if each is described in light of all of the criteria. Accordingly, this section presents such a description below. For convenience, key words are underlined to identify the criterion at issue.

Evaluation of the models against some of the criteria need not provoke a long discussion. All the models discussed here are <u>used elsewhere</u>. Each

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[2]The "permanent income hypothesis" underlies this expectation. This hypothesis claims that individuals attempt to maintain their consumption at about the same level even though they recognize that their income may go up or down during different periods of their lives. It has clear implications for investment behavior during disruptions. When the price of energy increases relative to that of other goods and services in the economy, consumers' real income falls. (They can't buy as much as they did before the disruption.) Since they view this income fall as disruption-induced and temporary, they attempt to maintain their predisruption level of consumption and can only do so by saving less. As a result, a smaller amount of national income is available for investment.

approach is frequently referenced elsewhere in the literature. In addition, current policy debates frequently focus on the advisability of particular prescriptions associated with disruption models.

None of these models makes <u>predictions about the transition to backstop technologies</u>. Accordingly, the models are not directly relevant to DoD policies on that issue.

These models do make important observations that can help to <u>estimate the value of stockpiles</u>. However, one cannot immediately translate these observations into dollar figures that represent the value of an additional barrel of stocks in excess of its costs. Accordingly, these models cannot be used to estimate the benefits that OMB might require DoD to show to prove the cost-effectiveness of a Defense petroleum reserve. Knowledge of how the models regard stocks can, nonetheless, enhance DoD's judgments about those stocks. The best example of this fact is that despite their many other differences in focus and recommendations, these models represent substantially the same view about stockpiles. They favor stockbuilding in normal markets and speedy drawdown in disruptions.

These models can <u>inform judgments about future price paths</u> although they do not provide predictions of what the world oil price will be in so many years. Moreover, whether a model contributes insight for policy depends on whether DoD decision makers accept its "story" for predictive purposes.

Verleger suggests that producers will revise contract prices upwards to match spot levels only after long time lags. In his view, this practice leads to higher eventual prices than would otherwise be required to balance supply and demand. If DoD decision makers find the Verleger argument persuasive, therefore, and if they are skeptical about whether a disruptions tariff will be imposed to make prices rise more quickly, they might revise upwards the estimates they form on the basis of other information.

Erfle's study can also inform judgments regarding the likelihood of future price paths, but it imparts limited insight. This is true even if DoD decision makers decide to accept the study's political explanation of past underpricing as sufficient basis for predicting the same behavior in the future. In this case, their only insight about future price paths will be that the product prices of major oil companies will not rise to efficient (i.e., spot market) levels quickly, if at all. This insight does not warrant major changes in the long-run price path the decision maker would otherwise expect.

Mork's work can also inform judgment about the likelihood of future price paths. In sharp contrast with the other two studies, the Mork analysis does not focus on a gap between spot and contract prices as a critical feature of supply disruptions. However, he does make some observations about the kind of price jump DoD decision makers might anticipate in a future disruption. For example, he used his quantitative macroeconomic model to simulate a 10 MMB/D disruption occurring for one year in 1985-86, and found a 35 percent increase in average oil prices for that period. This price shock is less than other estimates and contains an important lesson for DoD policymakers: macroeconomic analysis highlights the facts that disruptions can induce severe recessions and that in such recessions prices rise much less than one would otherwise expect. This lesson warrants DoD interest in how well particular forecasts factor in macroeconomic feedback effects. Forecasts that do not do so may tend to estimate higher price paths than actual outcomes might justify.